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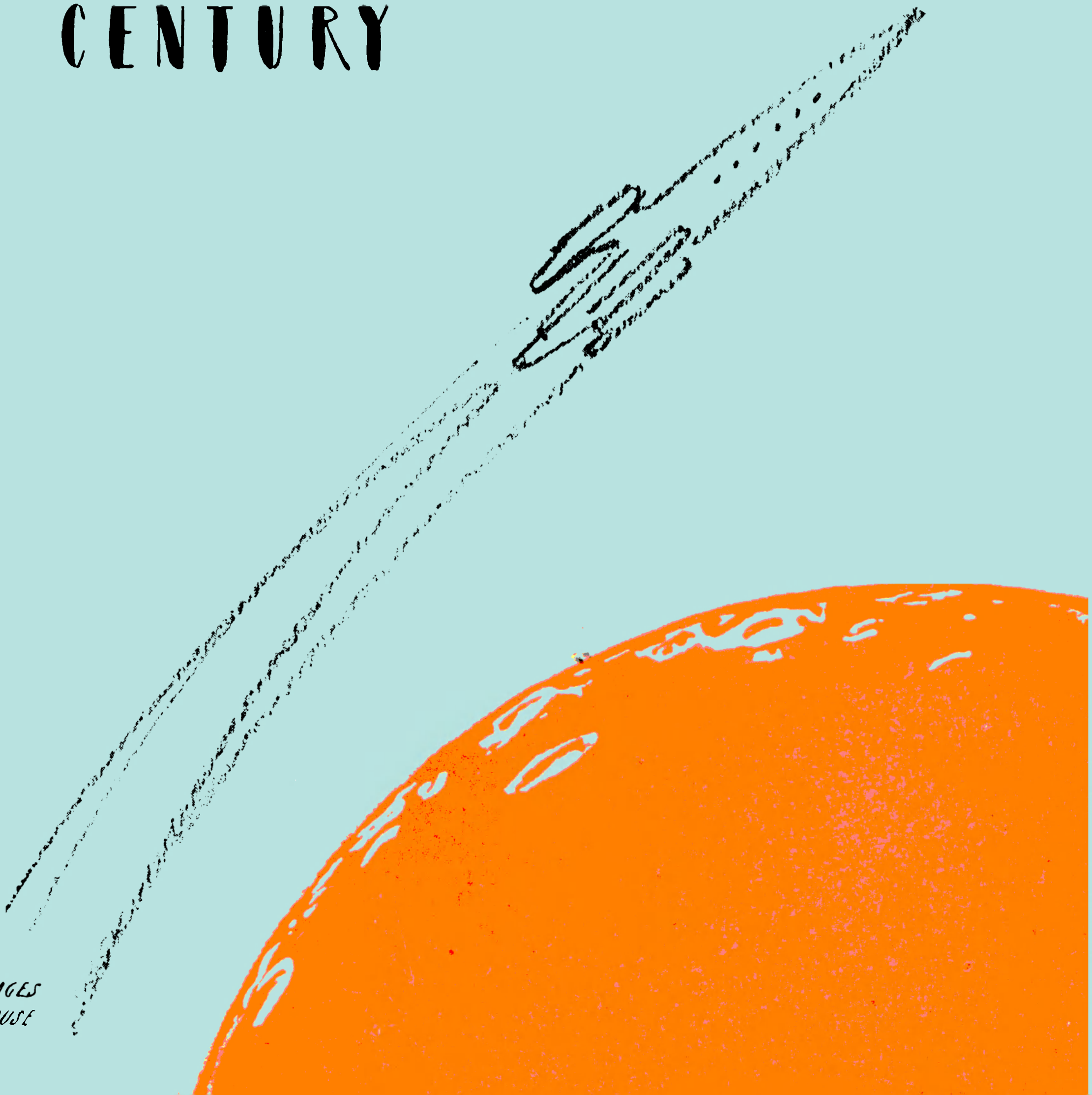
REPORTS from the TWENTY-FIRST CENTURY



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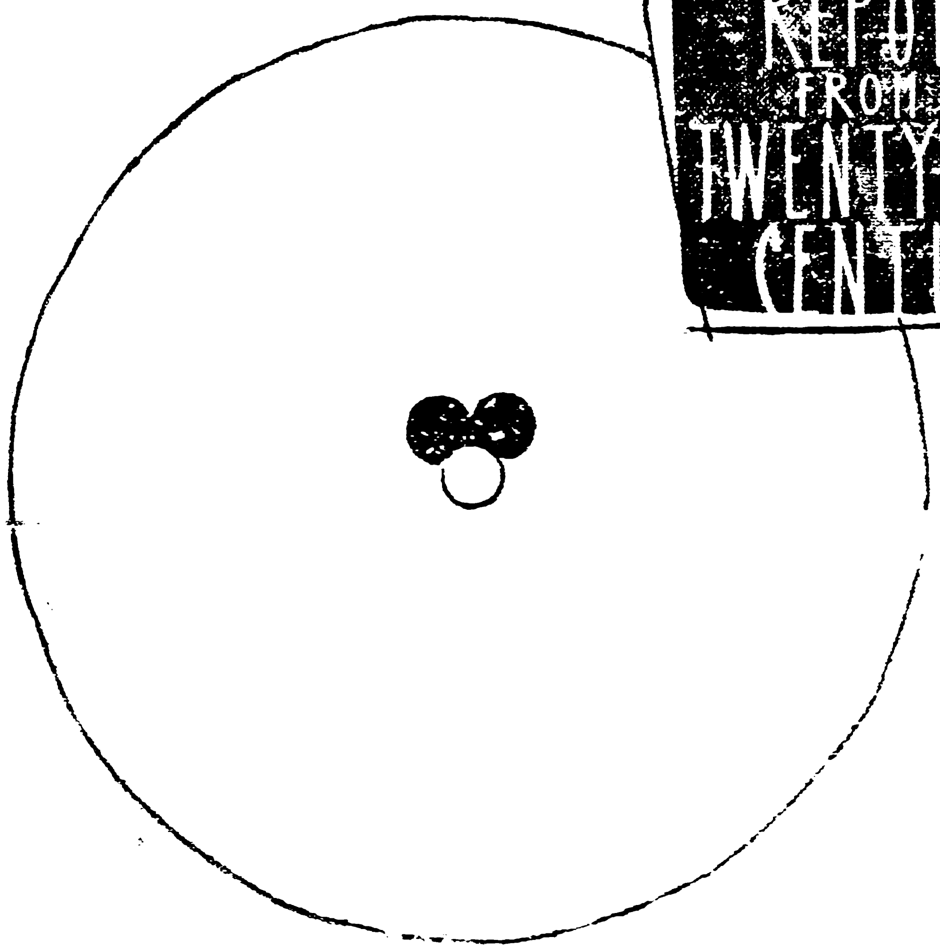

STORIES OF TWENTY SEVEN SOVIET SCIENTISTS ON SCIENCE AND ENGINEERING OF THE FUTURE

M. VASILYEV
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INTRODUCTION

From the Authors

We have met prominent scientists, engineers and inventors whose daring projects are aimed into the future. On behalf of millions of readers we asked them to do a little dreaming with us, try to foresee the developments in the branches of science in which they are working, tell us how their projects will be carried into life and what they will accomplish. Cannot biologists tell what the plant will be like by its very first shoots? We asked the scientists to point out to us the more viable, so to speak, shoots in the science of today and the most promising trends in its development, and to help us form a picture of the mighty plants that will grow from these modest shoots.

We asked the scientists to cast an eye not only at the nearest future, the years we include in our long-term planning, but to look beyond them, through decades, to the very turn of the twenty-first century and even farther.

The scientists very willingly consented.

To be sure, this was no easy matter. In the U.S.S.R. science and engineering are developing faster than ever before. Not so very long ago atomic power was a vision of a distant future, today uranium reactors are already being installed in giant electric stations. It was not so very long ago that means of conveyance capable of connecting continents in the space of a few minutes existed only in science fiction, today intercontinental rockets are a reality. Fancy bridging a gulf of fifty years yet to come, when an engineering project outstrips even the most daring fantasy?! But the scientists did it just the same.

Listening to the tales about the wonders science is to carry into life and engineering to bring within everybody's reach we seemed to live in the future ourselves. And this is why we feel justified in naming our reports of the interviews "Reports from the Twenty-First Century."

Learn to Dream

We are in Alexander Nesmeyanov's study. An inkstand with a bronze Titan supporting a sparkling globe on his shoulders stands on his large desk. The walls are hung with portraits of Russian scientists. In the corner we see laughing Lenin carved out of an enormous block of wood by the famous sculptor S. Konenkov.

We tell the scientist our plan.

After a brief pause the academician says quietly and unhurriedly: "I rather like your idea of casting a glance into the next century in order to get a pic-

ture of what will be done with the concepts only being born today. It is virtually propaganda of the most interesting achievements of modern science and engineering, something which is very important and useful. On the other hand, it is scientific dreaming, it is accumulated experience of scientific prediction of the development of science for a long period of time, something which is undoubtedly also helpful and important.

"To tell the truth, we are not always inclined or able to dream, and yet some dreaming is necessary. No dreams, no prospects. Without a dream to go by, every man, scientists included, must inevitably come to a standstill. But creative work and marking time are incompatible.

Poetry of Dreaming

"I should like to compare developing science with a tall, branchy tree whose roots all run deep into the ground. It is but natural to demand that science should bear fruit. In our socialist society science is essentially aimed at serving man, i.e., at satisfying man's material and, what is no less important, spiritual needs and requirements. But, however rich the juices that the tree absorbs from the earth, it cannot develop and bear fruit without sunshine. For the scientist this sunshine is a dream, a lofty, inspiring idea that gives him light and heat and creative power.

"The higher the level of engineering, the deeper the roots the tree of science strikes in industry. But, as the roots run deeper, does not the trunk of the tree grow taller and do not its branches reach ever higher, to the sun?

"On the basis of the enormous present-day achievements of engineering science must set itself ever loftier tasks the fulfilment of which may make a tangible contribution to the building of communist society, this age-old dream of man.

"The progressive, revolutionary-minded people of our country were always noted for their endeavours to see ahead. Do you remember how Radishchev,* that lucid mind and noble soul, always dreamed of a better future, of the time when Russia would be transformed. 'I see a century ahead,' he used to say.

"Think of Chernyshevsky who tried to depict in his works not only the interrelations of the people in the new and then yet unseen socialist society but also to look into the daily life of the people of the new world, to see their aluminium dwellings and discern the machines that would facilitate the labour of free mankind.

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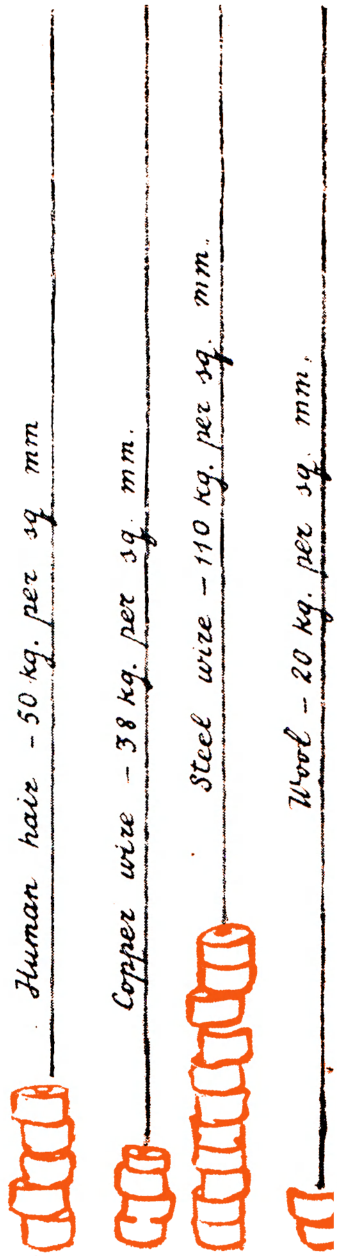
* Radishchev, A. N. (1749-1802), great Russian writer, revolutionary enlightener and materialist philosopher.

"Without this ability to picture the future at least in general outline people would be unable to solve the most complicated problems of science and of economic and political life. One must train himself in this ability. One must learn to dream and connect the work of today with the problems of tomorrow.

Wonders Are Becoming the Usual Thing

"The state of present-day science and the precipitate tempos of its development already warrant the boldest predictions of the future and not infrequently outstrip the rather slow science fiction writers. As a matter of fact, many of the problems now being solved by our scientists seem really fantastic.

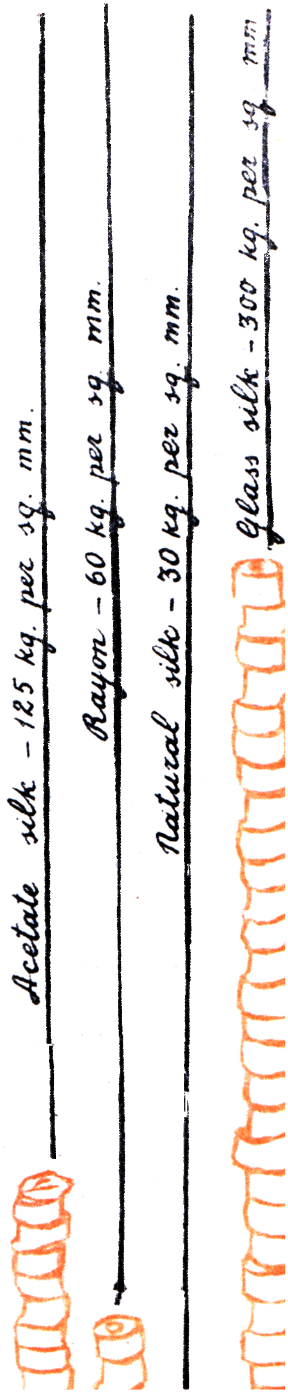
"The year 1957 will prove absolutely unique in the history of mankind. One of the things that happened during that year is so great that we, the contemporaries, cannot as yet fully appreciate its significance. The only events in man's history that can probably be compared with it are the discovery of fire, the production of the first iron, the invention of the steam engine and the mastery of nuclear energy. I am referring to the triumph of Soviet science and engineering in launching the first artificial satellites of the earth. Man-made heavenly bodies burst into space and have already made a visible and palpable contribution to science. The first cosmic laboratories have radioed to us the secrets of the ionosphere and cosmic rays and have told us about the behaviour of a living creature in interplanetary space.



"A revolution in intellectual work has begun. This revolution can probably be compared only with the one that occurred in industry when manual labour was replaced by machine work. I am speaking of the development of electronic computers which now take but a few minutes to make the mathematical calculations that formerly required months and even years of strenuous efforts of hundreds and even thousands of people. These machines make it possible completely to automate the operation of most complicated plants and to translate technical texts from one language into another. They can do the work ordinarily requiring large staffs of mathematicians, accountants and bookkeepers. Amazing reference machines containing and accumulating extensive information will be developed in the nearest future. Upon your request the 'electroreader,' a special part of this machine, will read all the machine contains, pick out, analyse and furnish you with the information you need.

"Physicists have invaded the innermost recesses of the atomic nucleus. Work aimed at utilizing the thermonuclear reactions for peaceful purposes is under way. We can already envision the development (not very soon, to be sure) of power stations operating on practically inexhaustible reserves of fuel, i.e., the nuclei of light elements, primarily hydrogen and its isotopes.

"The development of the antiproton and positron warrants the idea that it is possible to develop antisubstance.



Artificial fibres are not only as good as natural fibres but not infrequently are even better.

"I have enumerated but a few problems which only recently could not even have been dreamed of; today they are becoming reality.

"Science cannot develop without dreams, without looking ahead, into the future. A dream inevitably precedes a hypothesis which experimentation may transform into a scientific theory. Of course, I do not mean Manilov's* groundless philosophizing; I mean the ideas concerning the development of science based on its present-day achievements. The dreams of scientists are extrapolations into unexplored spheres and a scientific prediction. The prediction may be very daring and may take in the very distant future, but it must always be well-grounded.

"As a rule, scientists do not like to confide their dreams in other people probably because it is better to finish the thing first and talk about it afterwards. But don't you think that even these as yet unrealized dreams are very valuable? They are, as it were, landmarks discerned by the scientist on the way to the future and may serve as guides for those who follow. They may become the beacon lights which will lure many people into the kingdom of science.

"I should also like to emphasize that not only venerable scientists have the right to dream. The ability to dream is particularly typical of young people and one must incessantly develop this ability. We are living in a country where the realization of even the boldest dreams is a daily occurrence. But, of course, dreams do not come true by themselves. They can be effected only by work. One cannot come into science without hard work, purposefulness and persistence. Only by giving oneself to science completely can one accomplish anything in it.

"Young people usually dream daringly and the most difficult thing for them is to keep contact with the actual possibilities of today. To bear fruit a dream must strike root. It is much worse, however, not to look well ahead, not to see and not to set oneself a big and daring aim.

"The young people must learn to dream and to effect their dreams."

*

The academician paused briefly. The stenographer stopped writing. We waited with bated breath. In the very beginning of the interview we had asked the academician to tell us about the prospects for the development of organic chemistry. It is to this science, or one of its branches—metallo-organic

* A character in Gogol's *Dead Souls.*

chemistry—to be exact, that he has devoted his life. His works in this field have been translated into many languages. The scientists all over the world call one of the most important reactions in the synthesis of metallo-organic compounds the "Nesmeyanov diasomethod." Would the scientist tell us how he pictures to himself the future of one of the most amazing sciences, the science of wonderful transformations—chemistry?

Capron Wool and Explosive Potatoes

And, as if divining our thoughts, the academician said:

"Now I shall answer your second question concerning the future of my science, organic chemistry. This very rapidly developing science has already made enormous achievements and holds out even greater promises in the time to come.

"In the beginning young organic chemistry, the science that was born of the union of 'vegetable' and 'animal' chemistry, studied only the substances of living nature. But in the 1830s it began to develop independently. Its first achievement consisted in creating substances found in organisms. To be sure, it did not borrow anything from living nature but pursued its own course, the course of synthesis. By pursuing this course chemists were able to synthesize substances that do not exist in nature, for example, capron (a Soviet synthetic fibre), nitroglycerin and trotyl (explosives widely used in engineering). Zoologists do not know of any animal whose wool consists of capron, nor have botanists ever encountered any plant with deposits of trotyl in its tubers or seeds. The molecules of these substances, of many organic dyes that do not exist in nature, medicinal substances more potent than the ones offered by nature, and high-quality motor fuels have all been created by man and constitute the second great achievement of organic chemistry.

"The revolutionary significance of these achievements for technology may be illustrated by an example from the history of the dye-stuff industry. In the first half of the 19th century people wore clothes dyed by dyes only of vegetable or animal origin. In this respect their clothes in no way differed from those of the ancient Egyptians or Romans. Today our clothes are dyed only by artificial dyes.

"At one time vast areas of arable land in Central Europe were sown to madder whose roots yield alizarin which dyes fabrics red. The alizarin obtained from the plant is receding into the past and is being replaced by a better product in no way resembling the natural one. The same thing has happened to the crops of woad and other indigo-bearing plants which yield indigo blue. It can hardly be doubted that a similar fate will overtake the

crops of rubber-bearing plants. A whole scale of synthetic varieties of rubber is already in existence. Some of them are similar to natural rubber, others represent varieties of its structure and properties, while still others have nothing in common with it in composition and possess valuable new properties not found in natural rubber.

"Most of the people took no notice of the technical revolution of the end of the 19th century when the natural dyes were replaced by artificial ones in the course of but two decades. Similarly only few people now notice that many natural materials in our daily use are being replaced by artificial ones on an even larger scale.

"Much of what people have dreamed for a long time is now being embodied in flesh, and yesterday's fantasy is becoming the reality of today. Artificial fibre has come into our daily use quite unnoticed. Hardly anybody ever thinks of the wonderful transformation of a fir-log into a fine fabric, when putting on a shirt made of artificial silk. The purely synthetic fibres obtained from materials which have not the slightest relation to living nature are even more interesting. Capron, nylon, polychlorvinyl and many other fibres more beautiful, stronger and more hygienic than natural fibres are already widely used in the production of various articles, clothing and footwear. Recently you have learned of artificial astrakhan made in the U.S.S.R. from fibre called 'anid.' Artificial fur is replacing natural fur as rapidly as leather substitutes are taking the place of natural leather.

"I have no doubts whatsoever that in the future natural fibres, leathers and furs, like the natural dyes, will have to give way to artificial materials once and for all. Chemists can already produce and undoubtedly will produce fibres and fabrics with predetermined properties very much superior to those possessed by natural materials.

"There can be no doubt that in the 21st century people will wear clothes made only of artificial fabrics, shoes of artificial leather and coats of synthetic fur, and will be surrounded by things made of artificial materials.

"We are already making extensive use of such materials not found in nature. Your fountain-pen and comb, the case of your radio and the electric switches in your house are all made of plastics. Even the most 'inveterate' travellers have never described any plastic rocks, or plastic tree trunks or plastic animal horns. Nor has this material been created by man in imitation of nature. However, it has better properties and serves our purposes better than do natural materials, and this is why it is beginning to replace them all along the line.

"Whole epochs in the history of man's material culture have been named after the main material man used at the particular stage of his development. There was a time when a stone picked up from the ground and rough-hewn by another stone was man's only tool. That epoch in the life of mankind that lasted thousands of years was given the name of Stone Age. The Stone Age was followed by the Bronze Age and then the Iron Age. Leaving the generally accepted historical periodization aside I can aver that we have now entered the Age of Artificial Materials, the Age of Plastics.

"Strong as metal, plastics are beginning to take the place of metals. Plastics as resistant to acids and alkalis as platinum have already been developed. Plastics are now being used in sculpture, and marble will have to give way to them. In the new trolley-buses which the Muscovites see in the streets of their city the usual silicate glass panes that have come down to us from the Phoenicians have been replaced by organic glass which is much lighter, more transparent and passes ultra-violet rays. Elastic and beautiful the plastics may finally displace polished wood.

Rivals of Steel, Stone and Wood

"The interior of motor-cars is finished in plastics which imitate wood. If we cast a glance into the 21st century we shall hardly find anything that is made not of plastics but of substances taken in their invariable form from nature.

*

"All I have told you about are achievements of organic chemistry which operates with methods unknown to organisms found in living nature. I have already mentioned the fact that organic chemistry deviated from nature in the very beginning of its development. Even in creating the substances found in nature it pursued its own course and made no use of the methods by which nature produces the same things. Yet living nature synthesizes her substances in a temptingly simple and rapid manner. Suffice it to recall the work of our digestive apparatus, which breaks up our food into elementary structural 'little bricks,' and the synthesis in the cells of our body which uses these 'little bricks' to build the most complex substances of the muscular, bony and nervous tissues.

"We produce artificial rubber in a way that has nothing in common with the synthetic laboratory of the rubber-bearing plant. In the living cell the operations of the synthetic rubber works, frequently requiring very high temperature, are replaced by very fine influences of various enzymes at each stage of the process, the enzymes accelerating and directing the reaction.

Mastery of these ways of nature, this most intricate mechanism of chemical transformation, will be the third great achievement and victory of organic chemistry which shows a tendency of merging with biochemistry in the future. I am certain chemistry will be able to celebrate this victory during the current century.

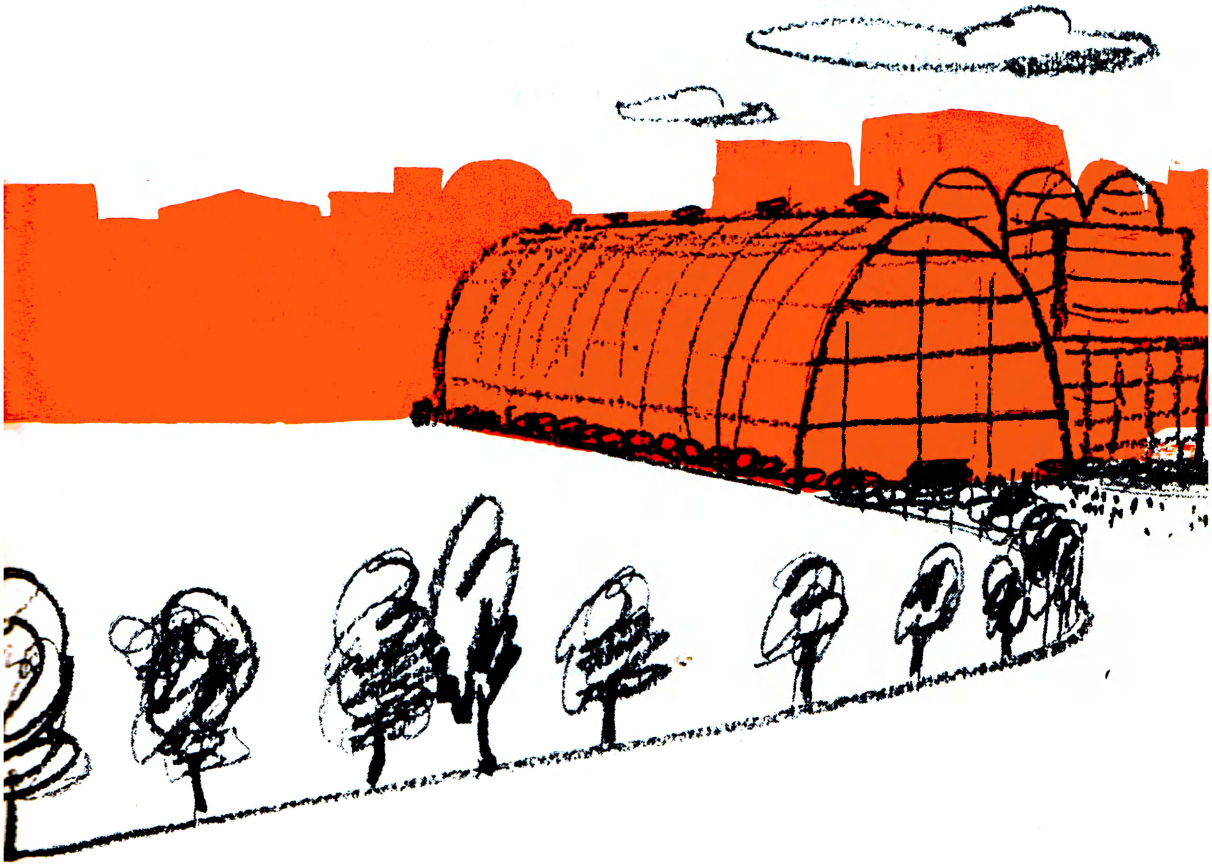
"In the beginning of this new stage in the history of organic chemistry—enzymatic chemistry—we shall probably master the secrets of producing the substances made in the living laboratories of nature. And then the time will come—we are still very far from it—when, using these methods inherent in living nature, we shall produce substances that are not found in nature.

Four Stages of the Science of Wonderful Transformations

"Thus we see the following basic stages in the history of synthetic organic chemistry. First stage—synthesis of substances, found in plants and animals, by methods unknown to nature. Second stage—development of an unlimited variety of substances, not found in nature, by the same synthetic methods. Third stage (which we have now entered)—production of substances, found in organisms, by the methods used by living nature (enzymatic methods). And, lastly, the fourth stage (wholly in the future) when by using the same enzymatic methods we shall produce new substances, not found in nature, by developing for it enzymes unknown to nature.

"It is as yet hard to say to what practical results these untrodden paths of organic chemistry may lead, but they may prove even greater than all I have indicated today. Mastery of the secrets of the chlorophyll grain and the intracellular transformations of the living organism may reveal the technology of the future production of artificial foodstuffs which will greatly exceed the natural foods of today in quality, usefulness and assimilability. Man will then find methods of utilizing the solar energy much more productively than by means of plants."

THE MAIN AND MOST IMPORTANT THINGS



Transformation of Elements—the Future of Metallurgy

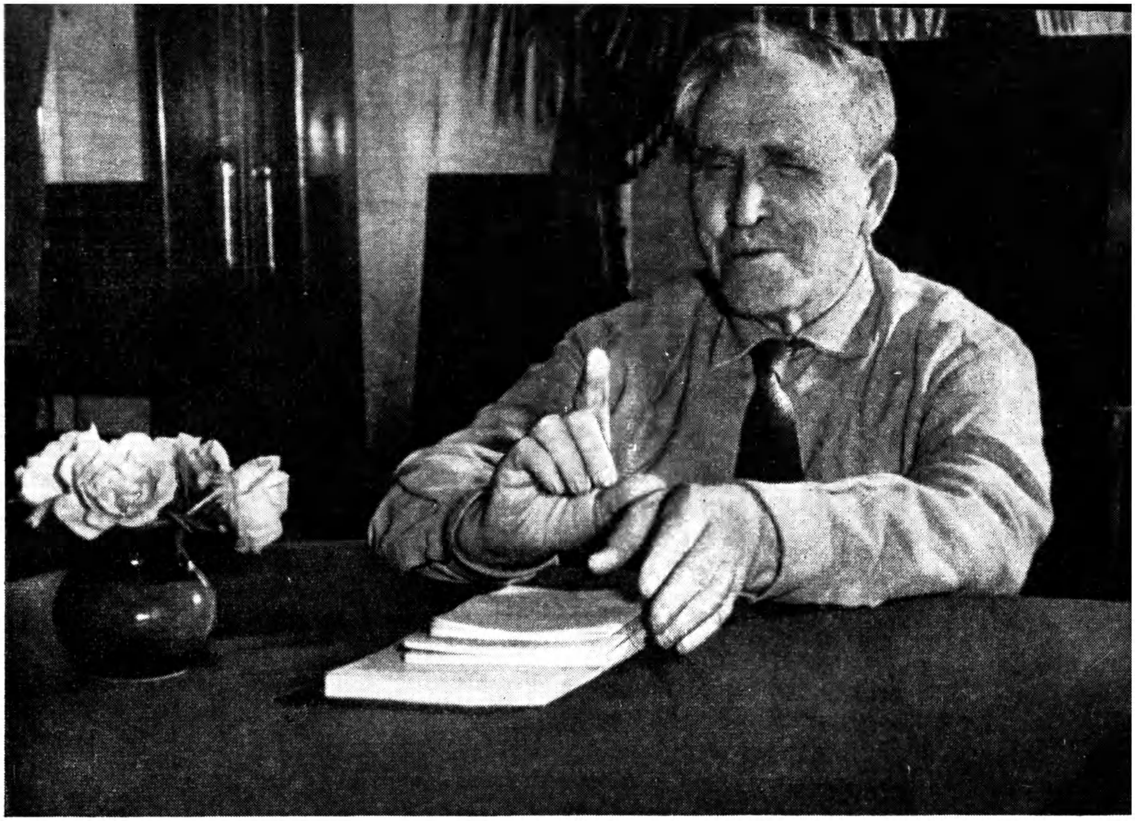
Mines Are Breathing Their Last

Automatic Oil Field

From the Sources

Power Resources in the Year 2010

Farkhad's New Hammer

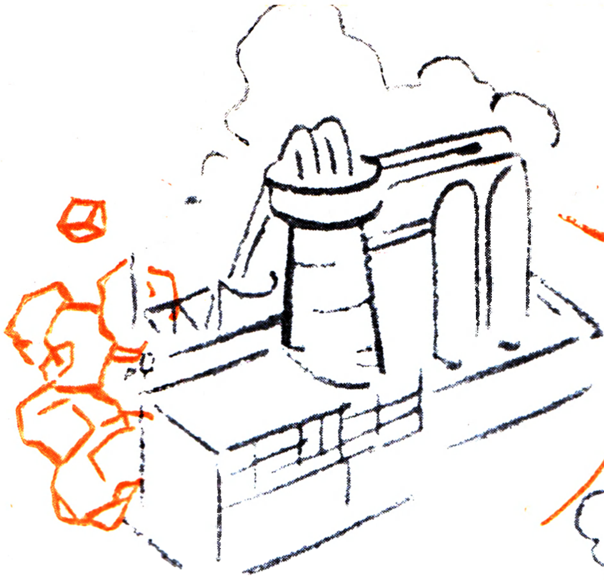


Transformation of Elements—the Future of Metallurgy

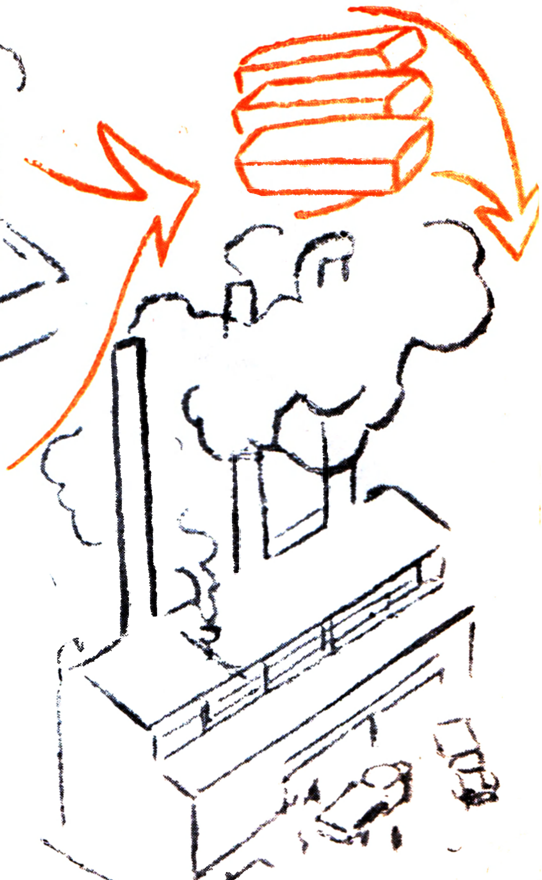
All sciences, including the most abstract and most theoretical ones, came into being because of some practical need. Astronomy was born because man needed an exact calendar and exact methods of navigation, and geometry because land tillers had to measure their plots of sown land. But the science about metal has probably always been one of the most practical sciences.

We were speaking to Academician Ivan Bardin.* He was past 70. We had

* Academician I. Bardin died January 7, 1960 at the age of 76.



Blast furnace



Open hearth furnace

come to see him at the very end of his workday. He looked clearly tired, but his face grew young and his eyes began to shine when he pronounced the words "the science about metal."

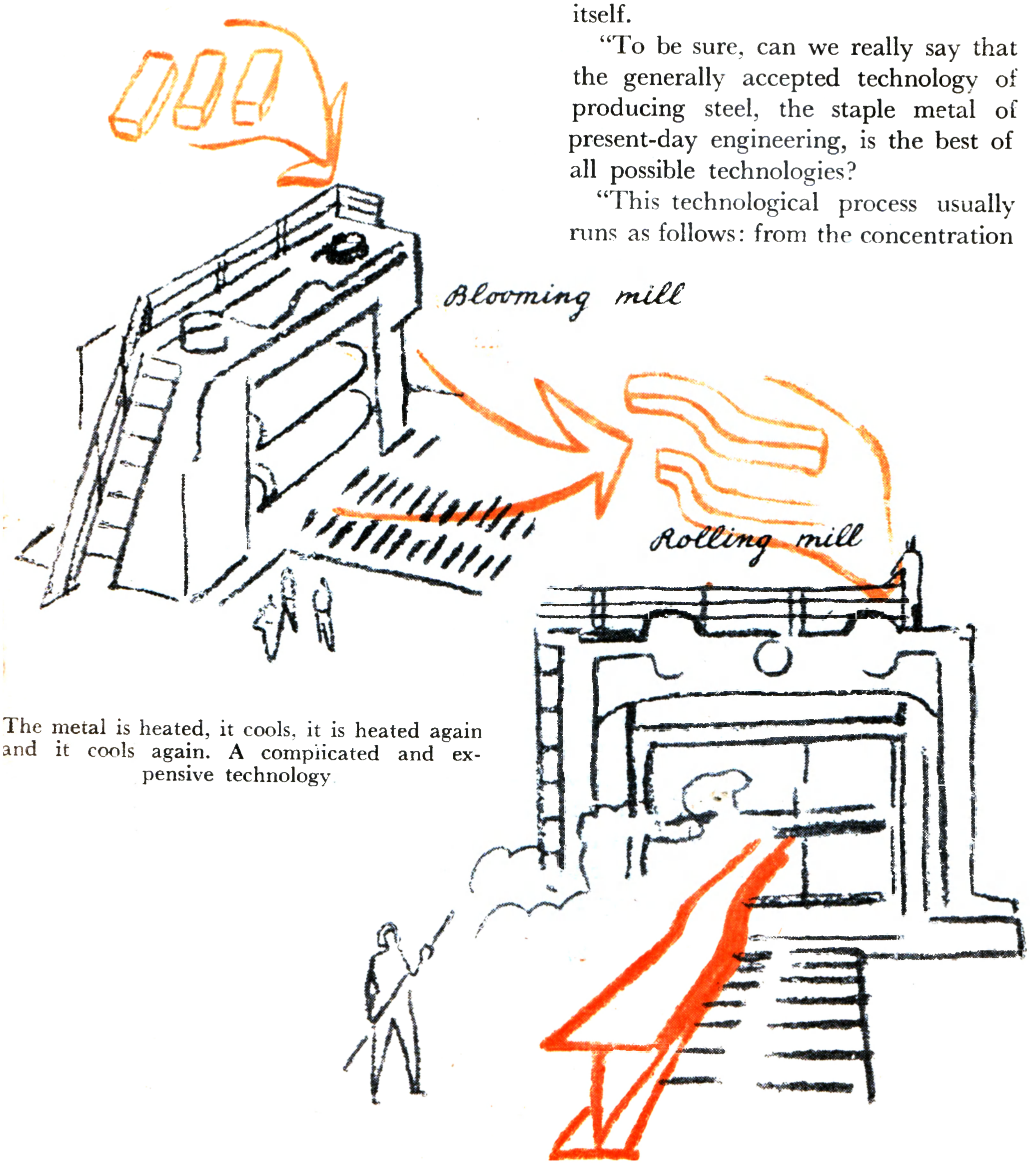
He was born in a rather poor family that never dreamed of giving him a higher education, but his mother's sister who was a school-teacher and her husband, a university student, inspired him with the idea of serving science. Bardin's biography is one of a self-made man. Upon graduation from a higher school he was unable to find employment in Russia and was forced to emigrate to America where he worked as a manual labourer because there, too, his degree in engineering was of no avail to him. He returned to Russia and, according to his own words, was very lucky to work with M. Kurako, a famous metallurgist. Then the Revolution drew a fiery line which, as Bardin put it, divided his life into two parts. After the Revolution he headed the construction of the Kuznetsk Iron and Steel Works, the giant firstling of Soviet industry, and then devoted himself to vast organizational and scientific

work aimed at expanding and perfecting the country's metallurgy. It is easy to understand why this man considered the construction of the Kuznetsk Iron and Steel Works the happiest time of his life.

"This science," says the academician, "came into being many thousands of years ago when man made use only of rare virgin metals. Later he learned to extract metal from ores. He still pursues this course, for new methods of producing metals and metal wares from ores still constitute one of the most important problems of this science today. You see then that during the many thousands of years of its existence the science about metal has not exhausted itself.

"To be sure, can we really say that the generally accepted technology of producing steel, the staple metal of present-day engineering, is the best of all possible technologies?

"This technological process usually runs as follows: from the concentration



The metal is heated, it cools, it is heated again and it cools again. A complicated and expensive technology

plant iron ore finds its way into a blast furnace where it is mixed with coke and heated. The iron is reduced and saturated with carbon, the resulting product being pig iron. Later this pig iron is smelted in special furnaces, the carbon is burned out of it and we get steel ingots. Before committing these ingots to the heavy rollers of blooming, slabbing and other rolling mills we must heat the metal several times again. But why couldn't we throw out of this technology all the intermediate power- and labour-consuming processes and at once obtain directly from the ore the steel of requisite composition as a ready-made article—rail, channel bar, or I-beam? Why shouldn't we make this intermittent process of today—first we get the ore, then we smelt pig iron, then process it into steel, etc.—a continuous process?

"I think we could and should, and future metallurgy will undoubtedly relinquish the technology of today. The modern blast and open hearth furnaces, Bessemer converters, blooming and slabbing mills—all these accessories of modern engineering will be rejected by the engineering of tomorrow.

"Of course, we must not expect to begin demolishing our blast furnaces and replacing them with new devices for the production of pure iron within the coming ten years. The blast-furnace process has not exhausted itself as yet, it is amenable to improvement and we are still building blast furnaces and shall continue to build them for a long time to come. Even today a blast furnace is a very intricate plant equipped with an enormous number of automatic devices and operated by but few workers. The blast furnaces of tomorrow will be completely automatic. They will be operated by electronic computers programmed to take into account all possible deviations from the designed process.

Automatic Blast Furnaces

"In the nearest future metal will be produced by a non-stop process. The blast furnaces will yield pig iron continuously, although even today a blast furnace producing 2,000 tons of pig iron a day puts out more than a ton of it per minute. Oxygen will be blown through the hot stream of the newly smelted pig iron and a hot flame will rise over the bath in which this process will operate. The flame will carry away the excess carbon, sulphur and phosphorus—all the admixtures that deteriorate the quality of steel. It will no longer be pig iron but a stream of steel that will flow into the moulds of continuous action teeming machines. Upon issuing from the moulds the steel ingots will be immediately delivered to the rollers of rolling mills and will be transformed into ready-made articles. It is simpler to automate such a continuous technological process than the present-day intermittent process.

"The structure of the blast furnace will probably also change radically, although perhaps not in the very near future. The device in which the metal is reduced will be a horizontal affair, something like a big revolving pipe. Refined powdered ore—a metal oxide without any extraneous admixtures—will be fed into the pipe at one end and a reducing gas, for example, hydrogen, at the other end. With such a technological process it is possible to produce metal in the form of a fine powder which after the addition of requisite alloying elements will be resmelted or immediately pressed.

These Are No Longer Blast Furnaces

*

"Everything that exists has its life span. It is said that turtles live 300 years, whereas horses rarely live to be 30. Metals also have their 'life span.' Of course, the life span of a metal largely depends on the conditions under which it has to live. The metal of a table knife has every chance to live longer than the metal of an aircraft engine since the knife, as a rule, experiences light stresses and the internal changes in its structure occur extremely slowly. Like the sluggish turtle it can live all of the 300 years. It is different with an aircraft engine. It leads a much faster life than even the fastest horse. Violent explosions rage in its heart—the cylinders—at the rate of hundreds or even thousands per minute. It is continuously shaken up; it vibrates and trembles. And it is really one of the greatest achievements of metallurgy that the present-day average life span of the mass-produced metal for motors, engines and machines is 35 years.

"But will the life span of metal increase in the future? It certainly will! Metal can have a much longer life than it has today. Do not the Damascus sword blades whose metal is protected with a thin layer of slags—oxides—live several hundred years? Of course, this metal was not produced by mass production methods in blast furnaces under a very high gas pressure and other unfavourable conditions of large-scale production. But we must strive to make the mass-produced metal in no way inferior in quality to the precious Damascus steel manufactured by the ancient masters.

Long Life to Metal

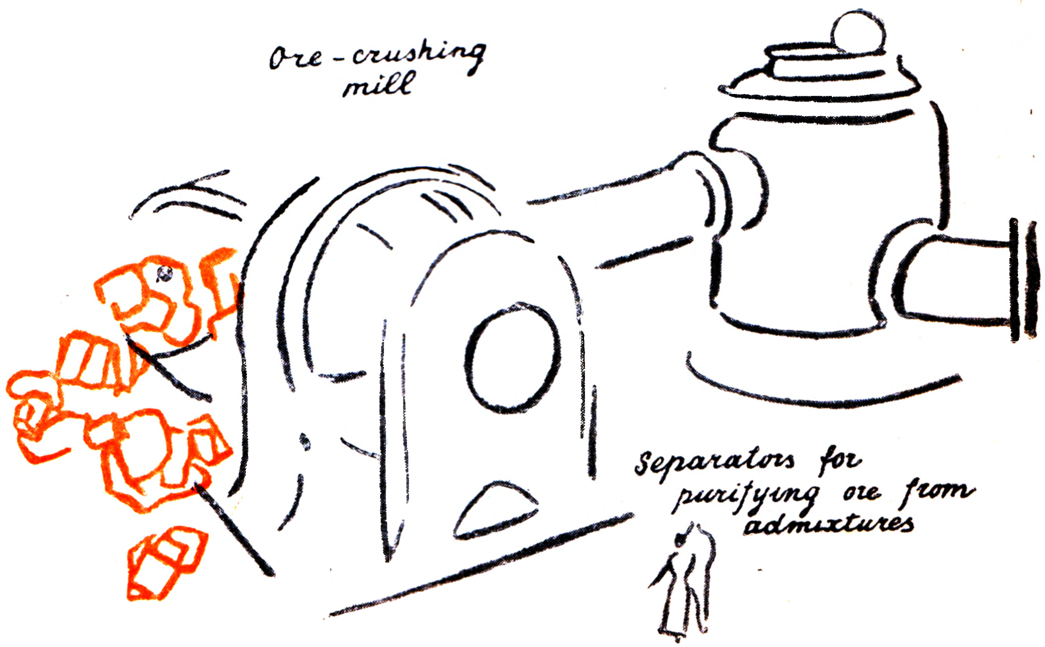
"To be sure, present-day alloyed steels, as, for example, stainless steel, live much longer than does even Damascus steel, but this represents an entirely different technological solution of the problem: Damascus steel contains no chromium, nickel or other metals which make up almost 25 per cent of the composition of modern stainless steels.

"It goes without saying that steel is the basic metal of modern engineering. But isn't the time coming when it will have to surrender its positions and cede its first place to other metals? It is usually thought that steel can be replaced by copper, the metal of electrical engineering, or aluminium, the winged metal, or yet by titanium, the young giant that is, in every respect, successfully competing with steel. It is correspondingly believed that the future age will be a Copper Age (doesn't electricity invade ever new fields of human culture?), an Aluminium Age (a widespread metal found nearly everywhere in nature, light, almost as electroconductive as copper, and as strong as steel in alloys—the metal of aviation), or a Titanium Age.

The Future Belongs to...

"I personally do not think that steel is in for very much trouble for the next 100 years. Of course, the production and importance of some non-ferrous metals are increasing at a very rapid rate. But then steel is also being produced in ever greater quantities. And whereas iron constituted 95.65 per cent by weight of all the metal produced in 1880, sixty years later, in 1939, when electrical engineering and aviation had already attained considerable development, the share of steel in the total production of metal constituted 94.06 per cent. In

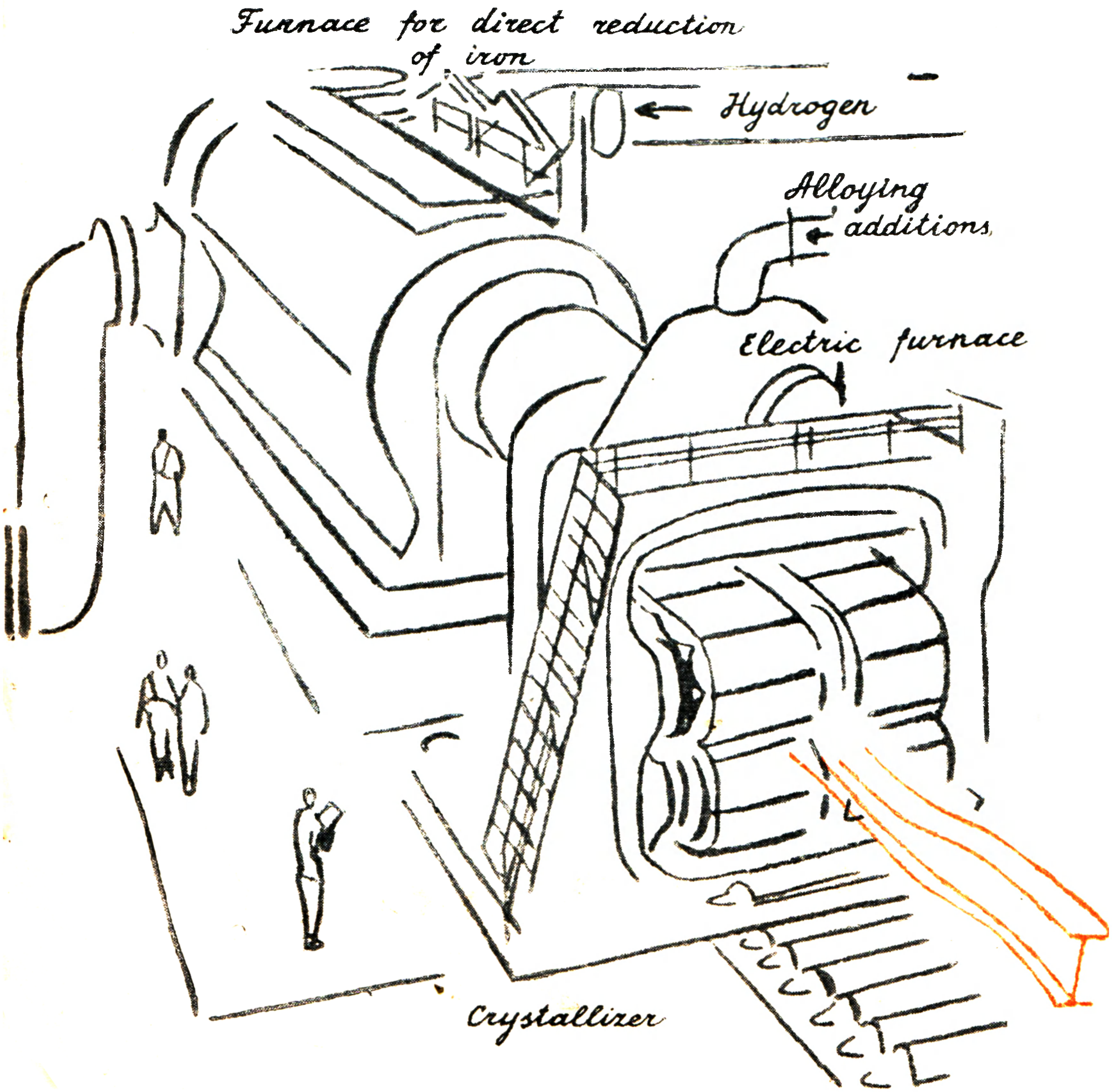
The technology of reducing the metal directly from the ore is much simpler.



other words, steel has retreated from its positions at the rate of 1.5 per cent in 50 years. And there are no indications that this rate may change so radically in the next 50 years.

"But aluminium, magnesium, copper, titanium and zirconium will certainly play an increasingly important part. This is especially true of titanium and zirconium. These two metals are usually believed to be rare, something that is not true at least of titanium which is one of the most widespread elements, the earth's crust containing 0.6 per cent of it (by weight). Titanium is very strong (twice as strong as steel) and relatively light (much lighter than steel).

"Titanium has one more extraordinarily valuable property—its high



resistance to corrosion. This most cruel scourge of metal takes a toll of about one-quarter of the world's steel production. But titanium fears practically no corrosion; in this respect it is as good as platinum. It is not afraid of any acids, alkalis or salts. Even when kept for many years in sea water it does not become coated with a film of oxide. *Aqua regia,* a concentrated mixture of nitric and hydrochloric acids, against which the noble metals—gold and platinum—are powerless, does not affect titanium. In the way of chemical stability it is 'nobler' than the most glorified precious metals.

"Titanium is extraordinarily heat resistant. It melts at 1,725° C, which is about 200° higher than the melting point of steel.

"It is precisely all these properties that make titanium an uncommonly 'dangerous' rival of steel. As a matter of fact, the production of titanium, begun in 1946, has been increasing with fantastic speed. In 1948 only 10 tons of titanium was smelted, whereas in 1954 this figure rose to 7,200 tons and in 1955 came close to 20,000 tons.

"We have already mentioned the fact that steel lives 35 years. Now we must say that articles made of titanium and zirconium will live for ages. They will be practically eternal. At the same time they will be much lighter than articles made of steel.

"The fate of titanium resembles that of aluminium. It was obtained relatively recently. Pure titanium oxide, a white crystalline powder, was first isolated in 1790. It required 120 years to produce a glittering silvery-steel metal, the first few grammes of metallic titanium. Scarcely more than 10 years have elapsed since titanium began to be produced industrially, but it is already referred to as the metal of the future and is predicted the most extensive utilization in aircraft, gas turbines, space rockets and numerous other branches of engineering. It surely gives iron something to think about.

"I want to touch upon one more question, i.e., a new way of processing steel for the purpose of enhancing its mechanical properties. The classical forms of such processing are as follows: thermal—hardening, tempering and annealing; chemico-thermal—cementation and nitriding; and mechanical—for example, cold hardening. Experiments show that a fundamentally new type of processing—irradiation with a stream of neutrons—will soon be added to them. When processed by this method steel acquires perfectly new, unexpected and wonderful properties. It is the problem of the nearest future to find requisite doses and methods of irradiation and to develop the necessary apparatus.

Hardening by Neutrons

"We are living in an atomic age. Man is mastering the much more important and thoroughgoing ties of the elementary particles in the atomic nucleus than the weak, unreliable and temporary bonds of atoms in substance. The achievements of atomic technology will find application in metallurgy.

"I think that, to begin with, man will 'construct' alloyed steels of the desired composition with the aid of radio-active influences without adding rare and expensive elements to them but by making them directly in the ladle of smelted steel from the atoms of iron, carbon, perhaps sulphur and phosphorus, and maybe from atoms of some other widespread element specially added to the melt for this purpose. This may be conceived as follows. A ladle filled to the brim with resilient waves of splashing steel is moving along. For a few brief seconds it stops at some machine resembling the ones used in medicine for the treatment of malignant tumours. A leaden pyriform vessel with a concealed source of radio-active radiation bends over the ladle, and most complicated nuclear reactions take place in the melt under the influence of the beam of rays. Several minutes later the steel is poured into moulds but its composition is no longer what it was but a short time before. The composition of the metal will continue to change in the already solid steel for several more days under the influence of its own radio-activity, caused by the irradiation.

"We shall probably be able to obtain the ores of rare and dispersed elements by the same method—artificial transformation of elements by changing the structure of their atomic nuclei. A new branch of industry—radiation metallurgy—which will produce rare chemical elements from the more common ones may possibly come into being. But even with our very rapid technical progress radiation metallurgy will hardly develop into a branch of industry even towards the turn of the century. It is still a matter of a more remote future."

Mines Are Breathing Their Last

First, an Excursion into the Past

As early as 1882 D. Mendeleyev, the great Russian scientist, wrote in his notebook a sentence which opened a new era in the history of coal mining. The brilliant scientist looked way ahead, and now, three-quarters of a century later, we are only witnessing the first attempts at introducing the method he foresaw into practice. We can confidently say, though, that in the 21st century this will become the main method and will displace all other methods. Here is the sentence taken from D. Mendeleyev's notebook: "To burn coal underground, transform it into lighting, generator or water gas and draw it through pipes. . . ."

We were talking to two persons: Ivan Garkusha, Director of the "Podzemgaz" (Underground Gas) Research Institute, and Nikolai Fyodorov,

his assistant. They handed the "baton" to each other so skilfully and imperceptibly that even the stenographer, as we found out later, was unable to separate the speech of the scientists. Only people, who dream the same dream, are absorbed in the same work and understand each other even without words, can be so mutually complementary as to continue each other's thoughts without in any way interfering with or inconveniencing each other.

There were two books on their desk, Lenin and Mendeleyev. Fyodorov opened one of them on the page he had marked. It was from this book he had quoted the aforementioned sentence. Garkusha took the other book in his hands.

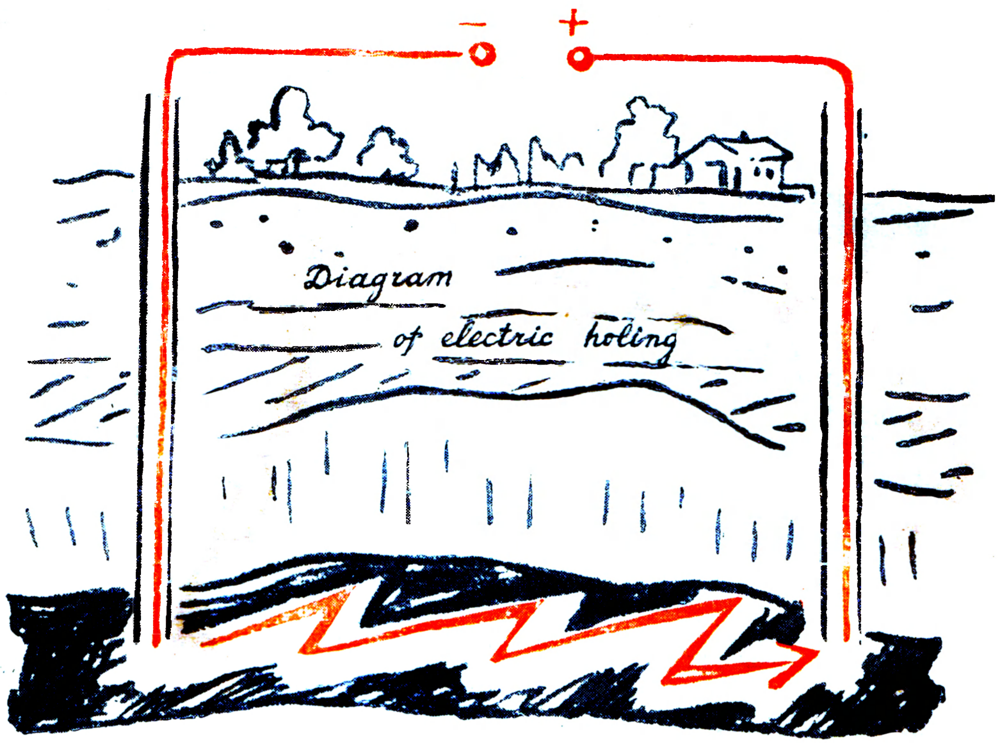
"William Ramsay, a British scientist, expressed the same idea of underground gasification of coal about 30 years after Mendeleyev. Lenin found out about Ramsay's works and on April 21, 1913 the *Pravda* printed his article under the title of 'One of Engineering's Great Victories.'

"Lenin wrote that this idea signified a great technical revolution that would bring about tremendous changes.

"In 1924 Lenin died, but the idea of underground gasification he had so fervently supported did not die as far as the Soviet Union was concerned. And it did not die largely because of this support. While studying Lenin's works some soldiers began to wonder why no research in underground gasification of coal was being done. The newspaper *Tekhnika* printed their letter under the title 'We Are Asking a Question and Demand an Answer.' Methods of underground gasification, cier, transformation of coal beds into combustible gases at the place of their occurrence, began to be elaborated in 1931.

"We should have said to begin with that underground gasification is one of the most complicated problems of modern engineering. It involves many branches of science: mining, chemical technology, electrical engineering, mechanical engineering, automation, etc. It was, of course, impossible to solve this problem offhand, but the very fact that towards the outbreak of the Great Patriotic War (1941-1945) Soviet scientists proved that Mendeleyev's idea could be carried into life should be considered a great achievement.

"New research in the field of underground gasification was launched after the war but this time the problem was tackled in an entirely different manner. In their pre-war experiments, before setting the coal on fire, the miners drove a gallery in the bed of coal manually and connected both ends of this gallery with the surface by vertical shafts. Then the gallery was set on fire. This



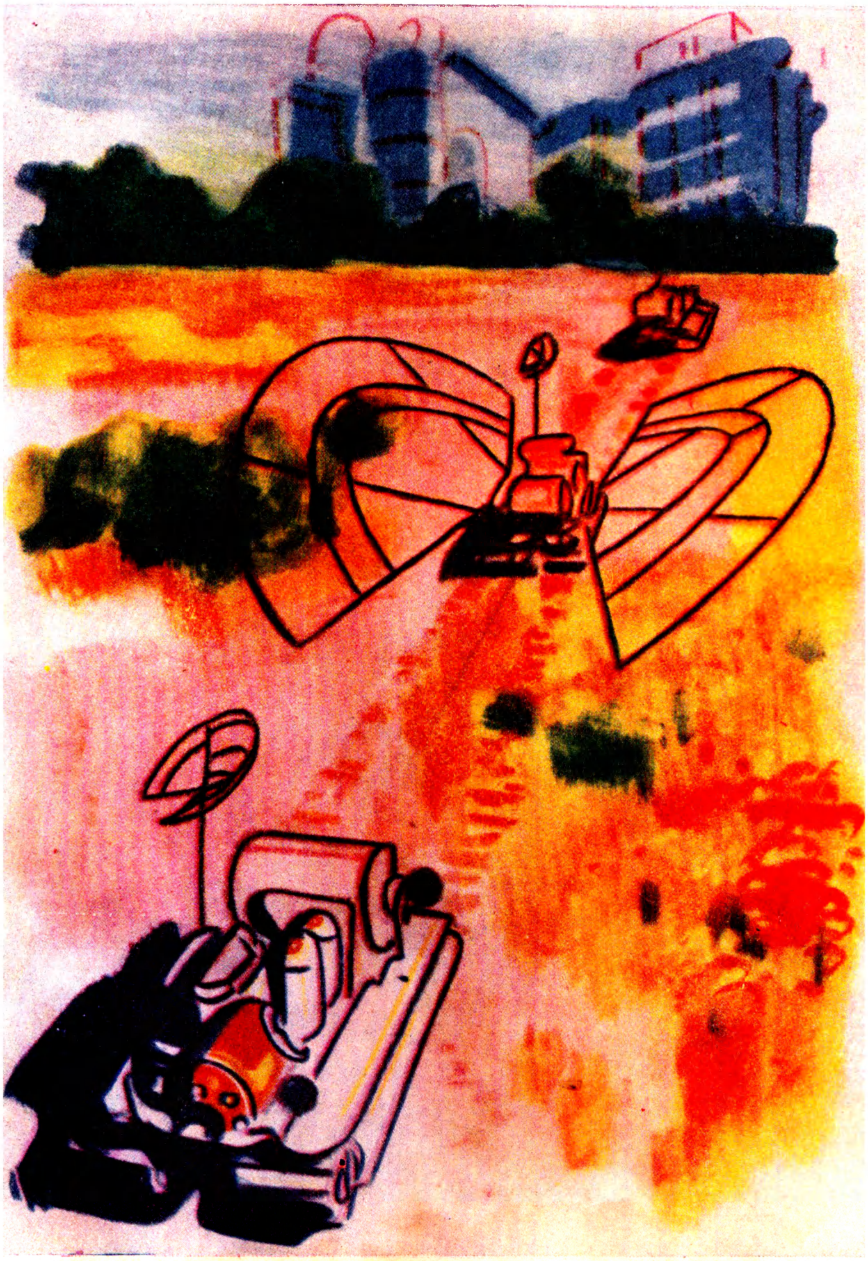
A hot spark of an electric discharge drove this "Pioneer" gallery in the bed of coal.

method required 5-10 per cent underground work just the same and considerably complicated the technological process. Today we are striving to prepare the coal beds for gasification without sinking shafts, i.e., we have decided to do away with all underground work.

"But how can we drive a gallery in a coal bed without going underground? We already know several ways of doing it.

Air Instead of a Drill

"If you sink two shafts at some distance from each other and pump air into one of them, the air will travel through the cracks in the coal bed and part of it will reach the other shaft. If we then set fire to this shaft the focus of combustion will gradually shift towards the stream of pumped air. A channel will gradually be 'burned' in



Within a few hours this bed of coal concealed under the yellow-green carpet of an autumn field will yield industrial gas.

the coal bed and will replace the gallery which we formerly drove by mining methods.

"This method was recently tried out in the Moscow Basin and is now extensively used at one of the 'Podzemgaz' stations in Tula.

"To drive the air through the coal bed to the neighbouring shaft, it is sometimes necessary to raise its pressure to 25, 50 and even 100 atmospheres, depending on the compactness of the coal.

"Considerable loss of compressed air which is merely dispersed through the coal bed is one of the shortcomings of this method. However, the total economic gain from underground gasification justifies this loss.

"Another method is known as electric holing. If electrodes are lowered into the shafts and high tension electric current is applied to them, the coal heated to 1000° C will be transformed into coke. Naturally, it is not the whole bed that will turn to coke. Experiments have shown that small coke veins, as thick as a pencil and excellent conductors of electricity, will form in the coal. Subsequent passage of current sparks off an underground lightning, as it were, this lightning cutting a gallery.

Underground Lightning

"There is one more promising method of preparing coal beds for gasification—horizontal drilling.

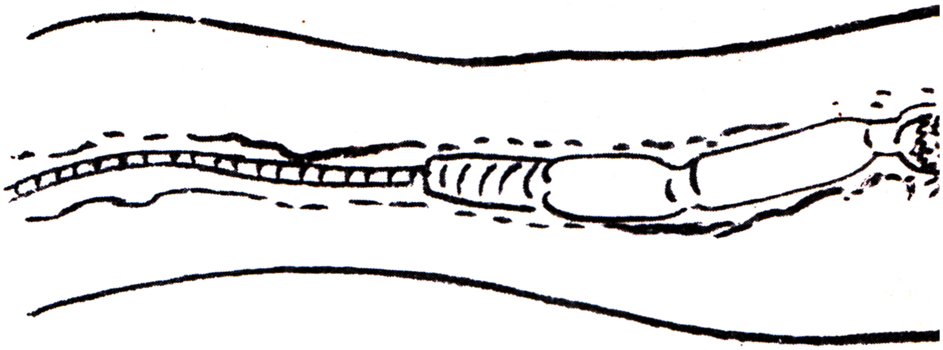
"This is not at all so fantastic as it appears. Our institute has already designed turbo-bits for driving horizontal tunnels. Nor is this a simple matter, since it is necessary not only to drive a horizontal tunnel but to drive it so that it may not go anywhere outside the coal bed. For best results it must be driven exactly through its middle."

The scientists opened an album and showed us drawings and diagrams. They called our attention to one of the figures showing a curved line that looked like a parabola, its apex resting against a horizontal co-ordinate.

"This is an experimental curve of distribution of the amount of elementary particles in a coal bed, the particles forming as a result of the natural radioactivity of rocks. The elementary particles 'flying' into the coal bed from the surrounding rocks are quickly absorbed by it. The farther away we move from the borders of the bed the fewer free elementary particles we find in it. Their minimum coincides with the middle of the bed. This circumstance may be utilized in developing device that will guide our turbodrill through the centre of the coal bed. We are now working on such a device.

The Drill Sees for Itself

"We must dwell on one more question. Mechanical shaft sinking is in no way the only or best method of driving through rock. We must expect some



This "seeing" drill sees elementary particles rather than light and moves to where there are most of these particles.

perfectly new and revolutionary proposals in this field. Very promising, in our opinion, is the use of ultrasound and directed beams of high frequency current.

"And now let us talk about the 21st century when, as we are convinced, man will no longer descend underground in search of underground treasures. Only investigators bent on discovering new secrets of nature will probably penetrate into the deep layers of the earth.

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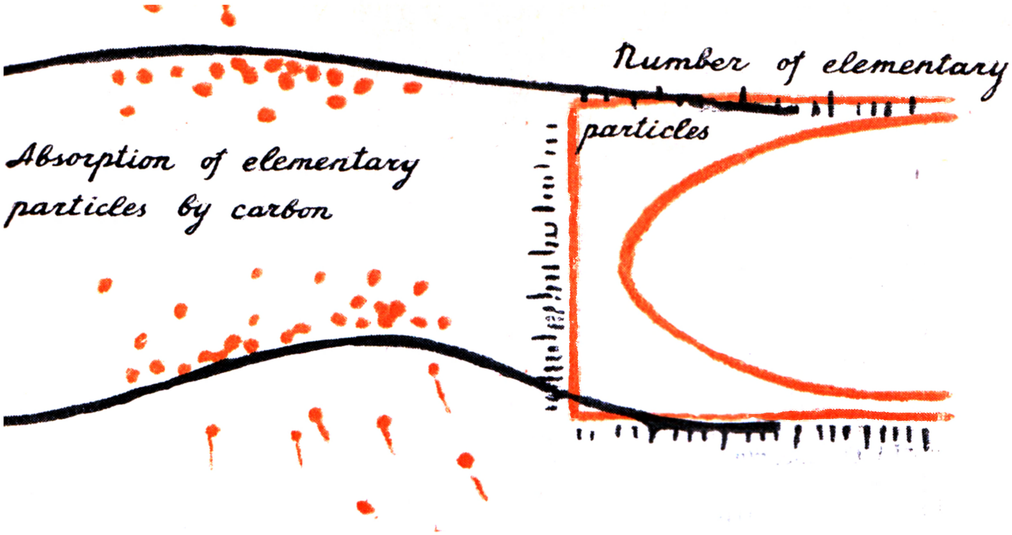
"In the 21st century the people will probably be perplexed when they see the giant earthen hills abundantly scattered, like Egyptian pyramids, through the planes of the Donets Basin, the steppes of the Kuznetsk Coal Basin and in many other places. An engineer or historian of engineering who chances to be near by will volunteer an explanation: 'These hills, heaps of the waste brought out of coal mines, are monuments of the period in the history of engineering when people had to descend into the bowels of the earth to mine coal with the aid of numerous cumbrous machines in low and narrow underground galleries. To prevent the wind from blowing the dust away from these hills, flowers were planted on them and they were turned into giant flower-beds. These coal basins are still densely populated and have highly developed industries using as raw materials the underground treasures which are far from being exhausted.'



"Of course, there will be some curious people who will want to know how these colossal plants operated, and this is what the engineer will tell them:

Impromptu Lecture

"Coal is still one of nature's most precious gifts. Like fifty years ago we use it for generating power and as a raw material for many chemical industries. But, whereas fifty years ago coal was mined underground, the railways transported it, and each heat and power plant, large railway station and boiler room necessarily had large coal stores, today we can see a piece of coal only in a geological museum. Today, for the production of power and for use in the chemical industries, we get only the gas produced by underground gasification. Combined power and industrial plants of underground gasification, in which gas is utilized in the most economic and efficient manner, have of late become particularly widespread.

"Incidentally, I happen to have a roll of film shot at one of these plants and, if you wish, I can demonstrate it to you."

Three heavy machines, their caterpillar treads glittering in the sun, are moving down a road running through sprouting crops. They are not driven by anybody and yet upon reaching an apparently predetermined point they stop and begin some strange evolutions. Two, at first sight similar, machines stop some 100 metres away from each other. Almost simultaneously light latticed masts rise over them. The third machine stops between these two and spreads wide wings.

The engineer continues his explanations.

Roving Machines

"This is an automatic underground gasification unit. The operator on duty at the plant gave these machines equipped with electronic devices an assignment to reach a certain point and set a bed of coal on fire in accordance with the general plan. What you see here," a bright light emitted by the pointer in the engineer's hand lengthens his arm and touches one of the end machines, "is a drilling installation that sinks shafts by means of high frequency current. A directed beam of high frequency emanations pulverizes the hardest rock. The fine sand thus produced is blown out of the shaft by a stream of compressed air. This box is a compressor which supplies the compressed air, and that thing there," the bright beam moves from one part of the machine to another, "is a generator of high frequency current."

In the meantime the machines continue their evolutions. The shafts are being sunk uninterruptedly; the high frequency bit needs no replacement for it does not dull; nor is there any need for jointing the pipes, since the bit and nozzle for feeding compressed air are lowered by a flexible hose unwound directly from large drums. The dials of the control instruments show the depth of the shafts drilled—30, 50, 70 and, at last, 100 metres. It seems the shafts have reached the bed of coal to be gasified. A few more evolutions and the third machine with its widely-spread wings comes to life. It begins to move slowly along a straight line connecting the drilling installations. To be sure, this is the machine that focuses the beam of high frequency emanations underground, at a depth of 100 metres, and "burns out" the first drift between the shafts.

Its operation is built on a simple principle. You know that if you place a lens in the way of solar rays it will collect them at one point where the temperature may rise very high. However, the layers of the earth are impermeable to rays of light but permit the passage of some kinds of radio waves. This machine concentrates a powerful beam of high frequency emanations in such a manner that the focus at which the high temperature develops proves to be in a coal bed deep underground.

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"All this appears amazing to us," said Garkusha, "but the people of the 21st century will view, without a shadow of admiration, the driverless machines performing most complicated and co-ordinated evolutions merely by carrying out an assignment given to them several hours previously."

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Leaving a sparkling line of steel pipes behind it one more machine appears on the scene. The steel pipeline made of elastic metal plates is being unrolled like a hemp fire hose. Before you can say Jack Robinson the end of this line is connected to the requisite branch pipe.

Despite the distinctness of the flashing frames it is difficult to get a clear idea of what is happening to the machines. The engineer describes it but in general outline. At last he announces that the coal bed has been set on fire and the plant began to receive underground gas. Let us give him an ear.

"About 50 years ago, at the very dawn of gasification," says the engineer, "the gas coming from underground at a temperature of about 600° C was immediately cooled in river water and the heat acquired in the interior of the earth was wasted. Today we are not so wasteful any longer. Of course, we, too, cool the gas—the film shows you birds sitting fearlessly on the metal of the pipeline—but we do it in special batteries with semi-conductor elements which produce electric current. This thermal energy brought by the gas is more than enough to run all the machinery operated at the plant.

"The underground process may be altered and, consequently, the composition of the gas produced may be changed, depending on the type of production turned out by the plant. Moreover, even the rare and dispersed elements which sometimes form part of coal but could not formerly be extracted from it are now produced at our power and industrial plants. Their production now includes almost half the number of elements found in Mendeleyev's Periodic Table, plus synthetic dyes, liquid fuel, alcohols, fertilizer, explosives, plastics and a great deal more. All the above are products of processing the different fractions of gas obtained underground."

The screen shows the plant's museum demonstrating the various products manufactured by it, an assortment any branch of industry of the middle of the 20th century could very well envy.

What Is This? A Mine? A Plant? An Electric Station?

"Not only products that are shipped by tank and truck are manufactured at the plants; high voltage transmission lines run from the power shops where the not very valuable residues of the gas that comes from underground are burned in the chambers of gas turbines. We recall that only 50 years ago nearly one-third of the coal mined underground was 'eaten up' by the voracious fire-boxes of locomotives. In the 21st century the energy concealed in coal also moves fast locomotives along steel tracks. But these are more powerful and economical electric locomotives, while the steam locomotives of

50 years ago can be seen only in museums. Some of the products manufactured at the plant are also dispatched by pipes. If we follow such pipelines we shall in all probability come to the shops of an iron and steel works. The blast furnaces of the 21st century operate on gas rather than on coke and the metal produced by these wonderful blast furnaces is very much superior to the pig iron produced by the old method. To think that a quarter of all the coal mined in the country in the middle of the 20th century was processed into coke for metallurgical purposes!"

The portable screen shows a light building rising above the verdure of a park; the walls of the building seem for the greater part made of glass. Sparkling pipelines, rustless despite the fact that they are always out in the open, run to and from the building. The people have long since found a method to prevent corrosion of the lion's share of the metal they produce. High voltage pylons diverge in all directions from the building, while automatic loaders are stacking neat crates on railway trucks. One after another the film shows the interiors of different shops with hardly a worker anywhere.

The engineer explains: "This is an automatic power and industrial plant, one of the superior achievements of our engineering, the engineering of the 21st century."

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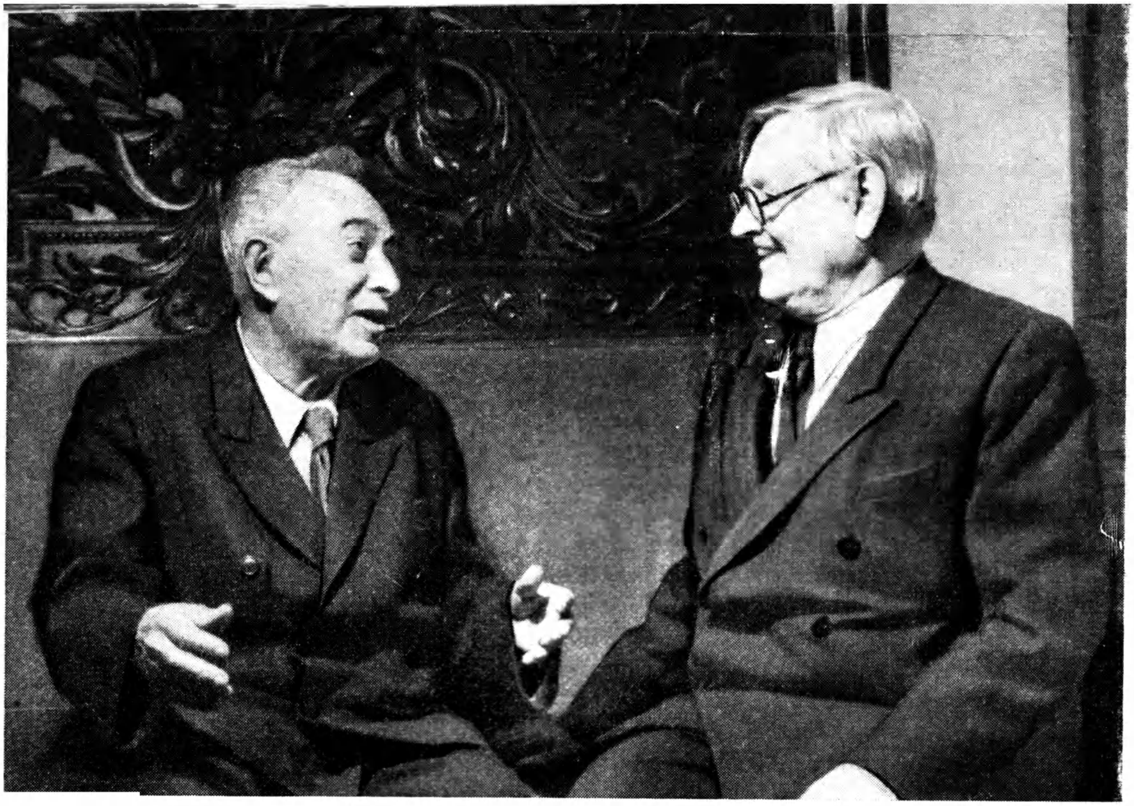
The film was over and the screen dark. We were again in the office of the director of the "Podzemgas" Research Institute looking into the slightly screwed-up eyes of our interlocutors who have just turned before us a page from the future.

"Coal is still one of the most valuable minerals," said Garkusha, "the backbone of the country's power resources. It is the fuel of electric stations and steam locomotives, but the transport will be one of the chief consumers of coal even when the steam locomotives are no more, since the power for electric locomotives will also be produced by thermal electric stations. In our country nearly one-quarter of the coal mined is consumed by metallurgy. Without coal we cannot have pig iron or steel, the principal metals of our time. The chemical industry requires more and more coal. A chemical plant transforms coal into liquid fuel and dye-stuffs, medicinal substances and plastics, oils and perfumes. The country will continue to mine more and more coal. But the day will come when coal mining is replaced by underground gasification because the latter will superbly satisfy the raw material needs of all of today's coal consumers; it will provide them with gas of requisite composition, a material of much higher quality than coal.

"The use of such gas for generating electricity is really uncommonly advantageous. It eliminates the need for large fuel stores, improves the sanitary conditions and raises efficiency. Railways show the same results when steam locomotives are replaced by diesel locomotives. It happens that metallurgists would also prefer to build blast furnaces designed to operate on gas rather than on solid fuel. Nor have the chemists any objections to working with gas rather than coal."

People Will Not Have to Go Underground

"Mendeleyev's brilliant idea so ardently supported by Lenin," said Fyodorov at the end of our conversation, "is but the first of the many ideas that will make man's work underground unnecessary. We are absolutely convinced that there will be no coal mines in the 21st century. And though we do not know so much about the prospects for the development of the other branches of mining we feel that 50 years from now there will be no need for iron, copper or salt mines. Don't we already extract sulphur by a mineless method? Superheated steam is pumped underground through shafts, the steam melts the sulphur and a heavy yellow liquid is pumped out through pipes. Common salt is also extracted by a mineless method. In this case water is pumped underground and a strong brine is pumped out. Analogously, probably by pumping underground the requisite acids or alkalis, we shall dissolve the ores of other elements needed for the national economy. In any case, man will no longer have to do any hard underground work."



Automatic Oil Field

Oil is the black gold of the earth and the hot blood of engines. The argument as to the origin of this oily liquid that impregnates the porous layers of limestones, sand and sandstones has been going on for decades. Has it come into being from the remains of animal and vegetable organisms that had gone down to the bottoms of seas or has it formed as a result of the reactions of some of the simplest hydrocarbons and metal carbides in the deep cracks and fractures of the earth's crust?

The great Mendeleyev defended the inorganic theory of the origin of oil. His experiments convincingly demonstrated that oil-like substances could be obtained as a result of the interaction of inorganic substances.

Other scientists proved with no less convincing experiments that oil-like products could also be formed of organic substances.

The organic theory of the origin of oil is generally accepted today. Basing himself on the inferences of this theory Academician I. Gubkin, a Soviet scientist, indicated new areas where no oil was known to exist but where, in his opinion, there had to be oil. Prospecting confirmed the scientist's prediction and offered the most convincing proof of the correctness of the organic theory.

But many controversial questions concerning the origin of oil and the structure of oil deposits are still unsolved. Many very important questions concerning the technology of oil extraction and processing still await their solution. As a matter of fact, the amount of oil extracted relative to its total quantity contained in a deposit, i.e., the efficiency of an oil field, which is one of the most important factors, barely constitutes 50 per cent, and this shows what enormous prospects there are for improving the techniques of oil extraction. And what about speeding up the drilling of wells, drilling them deeper and reducing the amount of labour per metre of well? The science about oil is far from having exhausted itself and in the nearest future it will require innumerable ideas and inventions and a great deal of effort.

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We were in one of the offices of the Institute of Oil of the U.S.S.R. Academy of Sciences, talking to Stepan Mironov, Academician, and Matvei Kapelyushnikov, Corresponding Member of the U.S.S.R. Academy of Sciences.

Both these men have long been working in science and have made numerous contributions to it; yet the two of them look to the future rather than the past of their favourite science.

Can Oil Possibly Be Edible?

"Oil is the most promising mineral for the next 50 years," said Academician Mironov. "The extraction of oil will increase and will surpass that of all the other minerals. There are many reasons for this. To begin with, oil is an extraordinarily valuable fuel, much more calorific than coal; besides, oil is extracted from the surface through wells and does not require any hard work of miners. Moreover, oil is a very valuable raw material for the chemical industry. Oil refining has already yielded thousands of products. Soon there may be scores of thousands of them. Polyethylene and cellophane, materials in which we wrap our foods, are produced from oil today. Tomorrow we may produce fats, proteins, sugar and other foodstuffs from oil. Oil is a raw material for the manufacture of plastics. You surely know that plastics are displacing met-

al, wood and stone. Plastics possess many very valuable properties. The 21st century will as surely be a century of plastics as our own century is one of metal. Oil will feed and clothe man and keep him warm; man will build more and more houses and machines from its products. For future science and industry oil will be more precious than gold."

Kapelyushnikov joined in the conversation but Mironov took up the thread again.

"And so more and more oil will be extracted with each passing year because there will be an ever greater demand for it as a most important fuel for various means of conveyance—motor ships, diesel locomotives, aircraft, automobiles, tractors, etc.—and a most valuable raw material for the chemical industry. But the question is: won't the world's oil resources run short in the nearest future and won't our civilization, very largely dependent on oil and oil products, face disaster?

"We can confidently say no!

"Thirty years ago scientists painted a terrible picture of exhausted deposits of Chile saltpetre, the most important fertilizer containing fixed nitrogen. Today this problem no longer agitates anybody because we now obtain nitrogenous fertilizer from the ... air. Only 20 years ago it was believed, according to some short-sighted forecasts, that the oil supplies would run low within some 15 years. We can bear witness to the fact that this forecast has also proved wrong.

"The U.S.S.R. is rich in oil. But very recently we thought that there was oil only in the Caucasus. Today oil is extracted in the Volga area, Central Asia and the Ukraine. Prospecting is under way in Byelorussia. Siberia has not had its say yet. Combustible gas deposits have already been discovered in Siberia and there is undoubtedly oil there, too. We can safely say that whatever the increase in oil extraction there is more than enough of it for a hundred years to come in the fields already discovered. Its total reserves may be estimated only with a knowledge of all the sedimentary rocks found on the territory of the country. The estimates are as yet incomplete.

There Is Enough for More than Our Lifetime

"How deep will the wells be? In the United States a well 6,500 metres deep has already been drilled, whereas in the U.S.S.R. the deepest well is 5,000 metres. These wells yield oil, consequently, there may be oil at an even greater depth. We can confidently say that, whether in search of oil or other minerals, in the 21st century wells will go down to about 15 kilometres. In all probability, either turbo- and electric drills or drills

The control board of the oil-field operator on duty showed a clear picture of all that was going on underground.

operated on entirely new principles—by means of high frequency current or ultrasound of directed explosions—will be able to sink such deep wells.

"How much of the oil shall we be able to extract?

"The following experiment is performed in laboratories. To dry sand only 5 per cent of oil by weight is added. This mixture is placed in a vessel into which a high-pressure gas is pumped. The gas dissolves the oil which passes into a vessel of lowered pressure and settles there. In the future we shall probably be able to do more; we shall be able not only to maintain the pressure in it, something we can already do by pumping water into the stratum by the so-called method of transcontour flooding, but also to vary the pressure by raising it to change the volatile hydrocarbons to a liquid state or, contrariwise, by lowering it to change them to gas. We shall probably also be able to regulate the temperature of the stratum. And then we shall extract from underground not 50 but 95-97 per cent of the black gold hidden in the bowels of the earth.

Changing the Course of Underground Rivers

"Another and no less important task may be undertaken. To-day we do not know the ways travelled by oil underground, although most of the scientists are beginning to believe that it migrates in the underground strata and that we now find it hundreds of kilometres away from the sites of its origin. There can be no doubt that man will come to know the laws of underground oil migrations. And as soon as he knows them he will learn to use them for his own purposes and direct the course of the underground oil streams to where they can be the most conveniently brought to the surface and utilized. And then the oil men will no longer drill wells where they think there is oil, but will direct the oil underground to the already available wells.

"Is this a dream? Of course, it is. But it took science less than 50 years to carry even greater dreams into life.Think of the radio. Scarcely three-quarters of a century has elapsed since its birth and yet it has already not only realized its dream of long-distance communication by means of the Morse code but has also made it possible to broadcast music and images. At the present rate of the development of science 50 years is a very long time.

"What will an oil field look like in the 21st century? It is not easy to picture it as it may seem.

"In the first place the methods of prospecting will probably develop to such an extent that geologists will be able to plot the exact outlines of deposits on

a map without a single metre of prospecting drilling and will begin industrial drilling at the site of future oil fields at once.

"The drilling rigs will probably be completely automated. One operator will run scores of rigs rising above the oil deposit. Diagrams will clearly show him not only the horizontal plan of the oil field but also the vertical sections of the earth strata. The operator will see the depth reached by the boring bit and the strata through which it passes in each well. If need be, he will issue a command and the well appearing straight as an arrow on the diagram will begin to curve on its way to the very heart of the underground treasury.

"At last the operator will reach the oil-bearing layer. There will be no more giant torches of burning oil gas, most valuable raw material and fuel, blazing in the wind. Special contrivances will catch it to the very last drop. Part of the gas will be burned on the spot to produce carbon black, an extremely important product for a number of industries. Nor will the heat liberated during combustion be lost; by means of semi-conductor thermoelements it will be transformed into electric current and used for the needs of the oil field.

"Part of the gas will be fed through light plastic pipes to the single gas network which, like the single high-voltage grid, will take in the whole country.

"The oil will also be pumped along similar pipes to the oil mains running to oil refineries.

"The operating engineer will begin the most important part of his work—regulation of the regime in the oil-bearing stratum located hundreds and even thousands of metres under the surface. Since he knows the chemical composition and properties of the particular oil (the oil of each deposit has its own peculiarities) he will control the pressure and temperature in the stratum in an endeavour to extract every possible drop of the precious substance."

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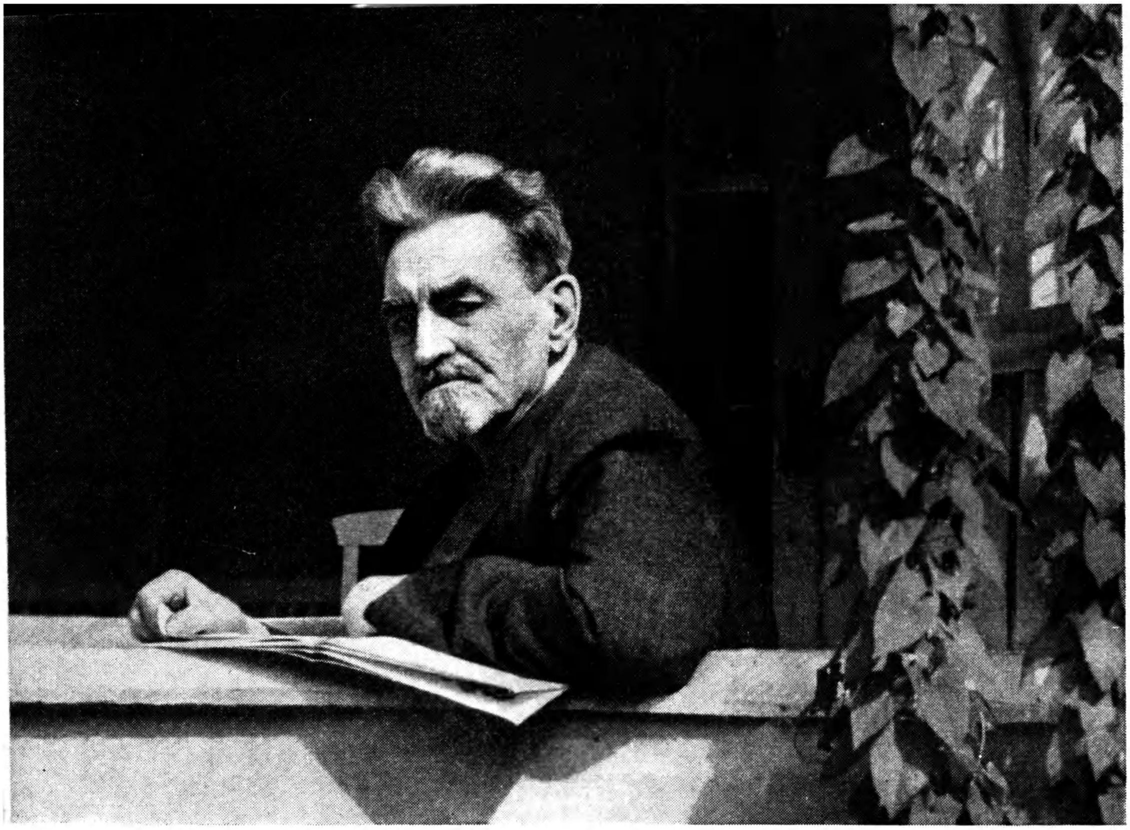
Our Pobeda was speeding along Lenin Avenue, one of Moscow's broad and beautiful thoroughfares. On the left we saw the white buildings of a famous hospital half-hidden in the verdure of the park that surrounds it and on the right the house designed by I. Zholtovsky and rivalling the hospital buildings in its noble and strict lines. The tyres rustled softly on the smooth surface of the asphalt just washed by a spring cloud-burst.

Asphalt owes its birth to oil. The synthetic rubber used in the manufacture of the tyres for our car is also an oil derivative. Petrol, a product of its refinement, explodes in the cylinders of the engine. It is the aromatic and transparent drops of petrol that contain the power which carries us softly and imperiously ahead. Nor could our car speed along the roads without a lubricant, another oil product. The plastic control knobs, the blue paint with reflections of the sun playing on its polished surface, the rubber mats and the insulation of the electric wiring—there is simply no end to the things in our immediate surroundings that spring from oil.

Wherever you may be—in a factory or at home, in your club or in the street—-take a good look around and you will always find innumerable near and distant "relatives" of oil.

The few pictures of the future cursorily painted for us by the scientists show how tremendously important oil, the black gold of the earth, is in our present-day life.



From the Sources

We shall never forget the somewhat lean face of the now deceased Academician Alexander Winter with its Vandyke beard and eyes looking directly at us from under bushy black eyebrows. After hearing us out he tapped with his fountain-pen on the green cloth of his desk and thought for a moment. We realized that pictures from the distant past, from his old experiences, rose in his memory.

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"After the victory of the October Revolution the young Soviet Republic inherited from the tsarist regime a very weak industry. The electrical industry was in a particularly bad way. Not a single, in any way significant, hydro-

electric power station had been built in tsarist time despite the fact that Russia had the world's greatest water power resources.

"As soon as Soviet power was established in Russia Lenin said that the country could build socialism only if its entire industry, agriculture and transport were electrified. I shall remind you of Lenin's classical formula: 'Communism is Soviet power plus the electrification of the whole country.'

"We began to build the Volkhov and Nizhnaya-Svir hydroelectric power plants as early as 1918. However, we had to discontinue work on the latter one and build only the Volkhov Station. In 1926 the Volkhov Hydro-Electric Power Plant was put into operation. Its designed capacity of 56,000 kw. seemed enormous at that time.

"A Commission for the Electrification of Russia, known as the GOELRO, was organized on Lenin's instructions in February 1920. This Commission was charged with elaborating a plan for electrifying and reconstructing all of the country's economy for the coming ten to fifteen years. The Commission finished its work at the end of 1920; its plan was reported to the Eighth All Russian Congress of Soviets in December 1920 and was approved. The work of carrying it into life began.

"The GOELRO Plan provided for the construction of 30 power stations—10 hydro-electric and 20 thermal electric stations—with a total capacity of 1,500,000 kw. In addition, it was planned to reconstruct some of the existing stations so that they would have a capacity of 250,000 kw. This plan was elaborated and adopted in 1920, the year that saw the production of only 500,000 kw-hrs of electric power.

"The GOELRO Plan was fulfilled in 10 years and was exceeded by almost 200 per cent in 15 years.

"In February 1927 the Soviet Government passed a decision to build a large hydro-electric power plant on the Dnieper River in the vicinity of Khortitsa Island, in the section of the river known as the Volchye Girlo. The power plant was designed by Professor Alexandrov and included a dam and a power house with 13 generators of 30,000 kw. each, the total capacity being set at 390,000 kw.

"However, soon after the beginning of the construction the technical part of the project was changed. More powerful units of 62,000 kw. each were chosen and their number was reduced to nine with the result that a more compact, cheaper and more powerful structure was built. The capacity of the Dnieper Hydro-Electric Station was set at 557,000 kw.

"The station was built in the shortest possible time—five years—and was the largest station in Europe. It continued to be Europe's largest till the time the Kuibyshev Hydro-Electric Power Plant was put into operation."

Outside the scientist's office window spring claimed its rights in the young leaves that had just broken out of buds. Before us sat a man who as a 23-year-old youth had been torn away from his student desk on a similarly fair spring day in 1901 and after four months behind bars had been banished under police supervision to Baku. He was a real revolutionary both in politics and science. While in exile in Baku, he took part in installing Russia's first steam turbines and an electric transmission line with a tension of 20,000 v. At that time this seemed a gigantic figure.

The "politically unreliable" Winter was able to go back to the institute only in 1907. In 1912, right after graduation from the institute, he began to work at first as assistant and then as construction chief of Russia's first electric station operating on peat.

Then came the Great October Revolution which opened up unprecedented opportunities, making possible all that had but recently been unthinkable. Winter became one of the creators of the extensive Soviet power industry. He was the construction chief of the Shatura and Dnieper electric stations. His contributions to science earned the country's highest appraisal and in 1932 he was elected Member of the U.S.S.R. Academy of Sciences.

This man has seen a great deal and knows a lot but how can he relate even a very small part of his experiences in so brief a chat? And as though the same thought occurred to him, Winter cut down on his story, short as it was.

"I shall not enumerate all the electric stations built in our country until very recently. There is something else I want to call your attention to. Another two or three five-year plans and all the power resources of rivers in the European part of the U.S.S.R. will be harnessed. We are planning to boost the country's electric power production to 320,000 million kw-hrs a year as early as 1960, which means that we shall be producing twice as much electric power in one day as we produced in all of 1920.

Half-a-Day Equals a Year

"Do you suppose that the development of our power industry and our hydro-power, in particular, will stop at that? Certainly not! The overwhelming part of our water resources is located in Siberia, on the other side of the Urals. It will take several five-year plan periods to place the power of the mighty Siberian rivers at the service of the national economy. It seems this

problem will be solved in the main just about the beginning of the 21st century. The Angara, Lena, Yenisei, Amur and other Siberian rivers will also be transformed into a chain of successive reservoirs propped up by dams of hydro-electric stations, as the Volga is today.

"We have already begun to harness the power of these rivers. Everybody knows about the first electric stations going up on the great Siberian rivers. The cascade of electric stations on the Angara River alone will have a capacity of about 9 million kw. and will produce more than 60,000 million kw-hrs of electric power a year. The same thing can be said about the Yenisei on which construction of the Krasnoyarsk Hydro-Electric Power Plant with a capacity of 4 million kw. is about to begin. One of the world's largest electric stations with a designed capacity of 6 million kw. will apparently be built on this river.

"Production of large quantities of extraordinarily cheap electric power on the Siberian rivers makes it possible to organize precisely there large-scale production of power-consuming goods, such as aluminium, rubber, magnesium, high-grade steel, etc. It can safely be said that in the nearest decades the centre of gravity of the industry will shift to Siberia with its extensive power and mineral resources.

"Will production of electric power in the U.S.S.R. continue to increase? It certainly will. Electric power constitutes the wealth of a nation and under our conditions, the conditions of socialist development, it cannot but increase. I think we shall be producing more than 1,000,000 million kw-hrs a year as early as 1970 and will soon probably outstrip the U.S.A. which is still well ahead of us in this respect. By the beginning of the 21st century the U.S.S.R. will apparently produce from 12,000,000 million to 15,000,000 million kw-hrs of electric power a year.

"Such is the history of electrification of the Soviet Union—from the tiny bulb burning in Lenin's study at the time the GOELRO Plan was being elaborated to the world's largest power plants already in operation or being put into operation. And such are our thoughts about the future.

"Recalling my meetings with Lenin I think of how proud he would be of our present-day achievements and how our grand, truly fantastic prospects would have inspired him, who was always so ardent and far-sighted."

Power Resources in the Year 2010

Valery Popkov, Corresponding Member of the U.S.S.R. Academy of Sciences, met us in the middle of his study and would not take a seat till the very end of our conversation. Energetic and quick, he simply could not stay put and his tall figure was constantly on the move.

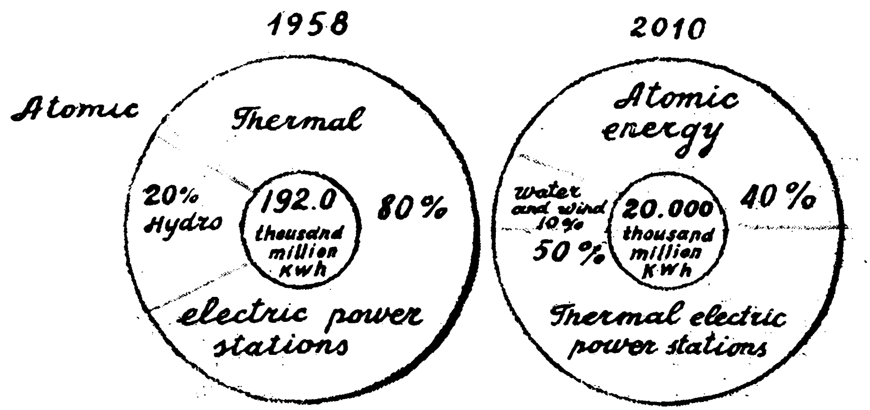
Speaking of generations, it should be noted that Popkov belongs to the younger generation of Soviet scientists. In 1930, when Winter was already a world-known builder of Europe's largest Dnieper Electric Station, Popkov was just graduated from the Institute of Energetics. He did not have to emigrate to America in search of work, as did Bardin; nor was he torn away

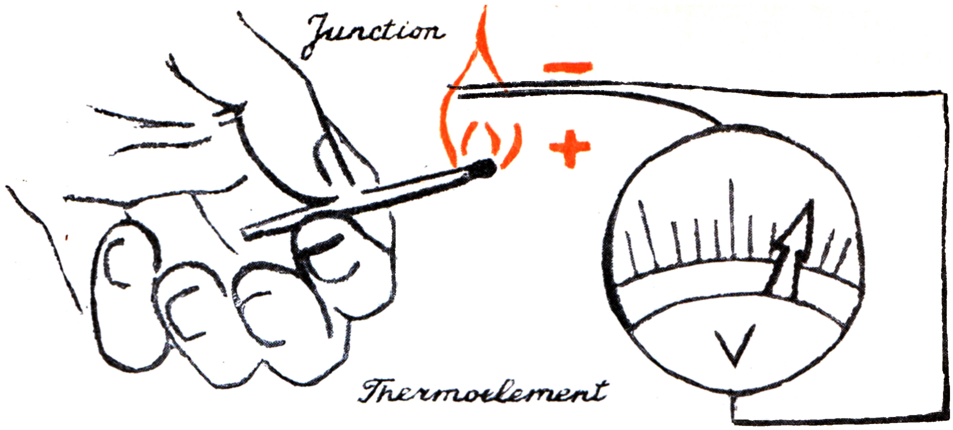
from his institute and banished, as was Winter. His creative talent developed and matured in a socialist society.

Popkov's principal scientific works are devoted to problems of high-voltage engineering and electric discharge in gases under high tensions, long-distance electric power transmission and the study of physical processes in electrofilters. Behind this dry list there are hundreds and even thousands of experiments, calculations and investigations which have helped in the building of the enormous Volga power plants and the world's longest and highest tension power lines, and which will yet contribute a great deal to the power industry of the future.

"The power industry of the 21st century will probably differ more from that of our time than our power industry differs from that of the end of the 19th century. Engineering is not developing along a straight line but along a steeply rising parabola. People understand and know from experience how important it is to have large quantities of electric power. I am sure that the figure of annual electric power production of 12,000,000 million to 15,000,000 million kw-hrs named by Winter will be reached in our century, whereas towards the beginning of the 21st century we shall produce about 20,000,000 million kw-hrs a year.

This is how the ratio in the power resources has changed.





Scientists know these direct transformations of thermal energy into electric power . . .

"You want to know how we shall arrive at this figure. To begin with, the share contributed by the thermal electric stations to the total installed capacities will in all probability go down from the 85 per cent of today to about 50 per cent. The thermal electric stations will meet the competition not only of hydro-electric power plants—in my opinion, the latter plus the possible new 'eternal' or renewable sources of power will be able to contribute at most 10-15 per cent of the electric power produced in the country. Atomic stations will offer much greater competition. I have an idea that by the year 2010 at least 40 per cent of the total electric power will be produced by atomic stations.

Coal Will Yield to the Atom

"Will the electric stations suffer any fundamental changes? I do not think the hydro-electric power plants will undergo any essential changes since they are efficient enough as they are. On the other hand, very substantial changes will have to be made in the construction of the thermal and atomic stations.

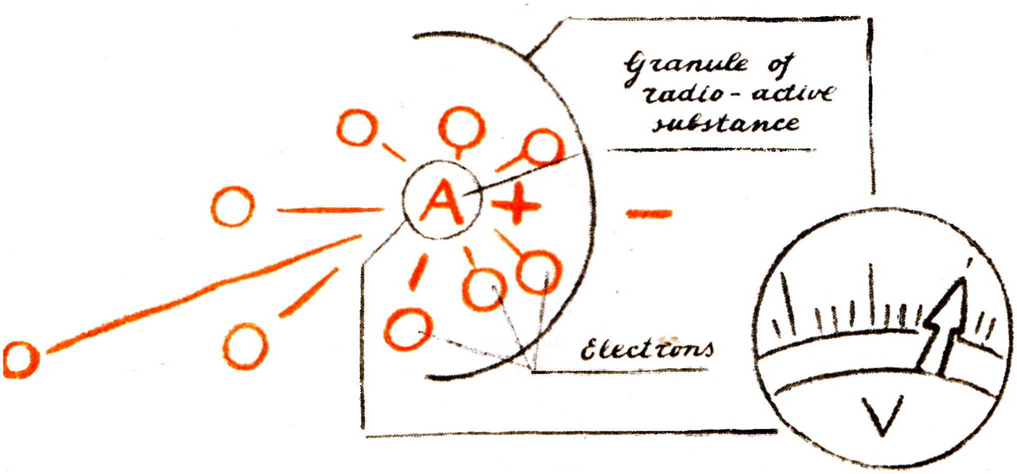
"Let us consider the thermal electric stations first. What is their chief shortcoming? It is their low efficiency. As a matter of fact, our thermal stations equipped with steam boilers, turbines and generators transform into electric power only about one-third of the energy contained in coal. One of the present-day practical methods of increasing their efficiency is aimed at raising the pressure and temperature of the working steam. In steam turbines with a capacity of up to 150,000 kw. the steam works under a pressure of

170 atmospheres and at a temperature of 550° C. Can you imagine such steam? Its temperature approaches that of red-hot metal. Modern heat engineering is taking advantage of the achievements of metallurgy in its endeavours to raise the capacity of individual units (boiler, turbine and generator) to 300,000 and even 500,000 kw. and of the steam parameters to a pressure of 300 atmospheres at temperatures of 650° C. This will make it possible to bring the efficiency close to 40 per cent. But this is the 'ceiling' and to go beyond it requires qualitative changes in the methods of transformation of energy and, in the first place, exclusion of the thermal energy stage—the energy of disorderly movement of molecules—from the chain of transformation leading from the primary source to electric power.

"I am certain that the electric stations of the future will do away with the long series of energy transformations necessary today. Just think of it: the chemical energy of coal is transformed into the thermal energy of steam, following which this thermal energy is transformed into kinetic energy—first of the streams of steam and then of the rotor of the turbogenerator—and only this mechanical energy is finally transformed into electric power.

"Our present-day atomic electric stations are essentially the same thermal electric stations in which the steam boiler has been replaced by an atomic

and atomic energy into electric power even today. But the efficiency of these transformations is still very low.



reactor. Together with the fundamental scheme of operation they have inherited their low efficiency. Do you know that the efficiency of the world's first atomic electric station is below 17 per cent?

I Can Foresee Two Revolutions

"I believe the second half of the 20th century will be marked by two revolutionary discoveries in the production of power: discovery of a simple and cheap method of producing electric energy directly from the chemical energy of fuel, on the one hand, and atomic energy, on the other.

"In principle such transformations are possible. I shall remind you of the fact that today we already have semi-conductor elements in which the energy of nuclear disintegration is transformed directly into electric current.

"In principle the chemical energy contained in usual, non-nuclear, fuel can also be transformed directly into electric power without going through the thermal energy stage in a manner perfectly analogous to that in which it occurs in the ordinary battery of a pocket flash-light. But it takes long, arduous and fascinating research to put principles into operation on a large scale.

"It appears to me, the thermal and atomic electric stations of the future will not have the numerous halls and their usual various machines. They will, in all probability, consist of some sort of a closed reactor into which the 'fuel' will be fed gradually, while direct current will flow from the reactor to electric lines along copper bars. Such electric stations will be as highly efficient as the present-day hydro-electric power plants."

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The scientist walked up to the map of the country covering a whole wall in his study. The pointer in his hand moved rapidly over the green spots indicating plains and the brown showing mountain ranges.

"I should like to dwell on one more technical problem—the creation of a single high-voltage grid which will receive the power from all of the country's electric stations and will supply all the consumers. This network will embrace the entire territory of the U.S.S.R. and will merge, for mutual advantage, with the power grid of China in the east and the grids of the European Peoples' Democracies in the west.

Distances Will Be Subdued by Millions of Volts

"The greatest distance over which electric power is transmitted today does not greatly exceed 1,000 kilometres. But over this grid electric power will be transmitted much farther. The tension in the power lines will have to rise accordingly. The transmission of alternating current of 400,000 volts from Kuibyshev to Moscow appears

amazing to us today. In the 21st century, however, a direct current tension of 1.5 million to 2 million volts will probably be the usual thing. Very long lines will no doubt work under still higher tension.

"What will such power lines look like? It will undoubtedly be necessary to find a new solution for the problem of electric insulation; it will be necessary to make the electric materials and, especially, the air surrounding the electric installations and wiring capable of sustaining such tension. It can be safely averred that underground cables will be used for long-distance transmission along with overhead lines. In addition to alternating current, there will also be direct current lines.

"I am devoting myself to problems of high tension which is my narrow speciality in science. Tensions of several million volts are still *terra incognita* to me. But for the scientists of the 21st century, working in the same field of science, my present-day endeavours will be a thing of the remote past. In their laboratories they will produce and study tensions of scores of millions of volts."

Farkhad's New Hammer

Do you remember the wonderful oriental legend about Farkhad (the people's hero) and beautiful Shirin? They loved each other so faithfully and ardently, but fate placed what looked like insurmountable obstacles in their way. Farkhad had to break through tall and rocky mountains so that he might later, after many years of hard work, unite with his beloved one. His heart was filled with a lofty passion and he did not spare his youth, his tremendous unspent powers or his very life to attain his cherished aim.

Farkhad is immortal. He represents all of mankind indomitably struggling for its aim through mountains of time and labour.

And the image of beautiful Shirin stands for peace, happiness and creative work. What profound meaning, what beautiful poetry this legend expresses!

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Lyre, Palette and Trinitrotoluene

We were visiting with Professor Georgy Pokrovsky, one of the most prominent specialists in blasting engineering and in the very beginning of our conversation he revived this remarkable ancient legend with such verve as would do honour to many a poet. Incidentally, we knew that the professor was really writing verse on the romance of science and labour. He also illustrated many of his own articles. He painted landscapes in oils and at family gatherings played music of his own composition. It is even hard to believe that this cheerful person inspired with the beauty of life had to do with substances fraught with terribly destructive power.

The professor seemed to divine our thoughts.

"For hundreds of years," he said, "explosions served as means of destruction. The only thing scientists formerly strove for was to make explosions more powerful. The development attained by science in the 20th century makes it possible to produce explosions of practically unlimited power. Today scientists are saying frankly that the use of superpower explosions (for example, atomic or hydrogen) for military purposes will endanger not only individual cities and countries, but also all of mankind, the whole world. Military blasting techniques have reached their 'ceiling'; they have advanced to the point which only madmen would overstep. But I hope this never happens.

"That is why today it can be a question of utilizing the tremendous power of explosions only for peaceful and constructive purposes.

"Let us cast a glance into the relatively near future when Siberia will be covered with a network of rail- and highways running mainly in west-east direction, when the shortest route from Western Europe to Peking will run through Soviet Central Asia and Kazakhstan. The strengthening friendly relations between the peoples of Asia and their rising economic requirements will make it necessary for the people of our hemisphere to cross within the coming decades the Himalayas and the entire mountain zone separating Northern Asia from Southern Asia. In time mankind will grow convinced that roads running north to south (along meridians) are of greater impor-

tance for the world economy than the present-day latitudinal communications, and man will need a means of smashing the wall between the north and south. An explosion will be this means.

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"This happened in the Chinese People's Republic during the construction of the Paoting-Chengtu Railway. To straighten out the course of a meandering river the Chinese builders had to split in two a mountain that was in their way. Aided by Soviet specialists they resorted to powerful explosions. The river rushed down the mountainous bed. A new series of guided explosions and one more furrow cut across the mountain, while within a very few seconds two fine railway embankments rose along the river. The direction, height and even shape of the embankments had been determined beforehand.

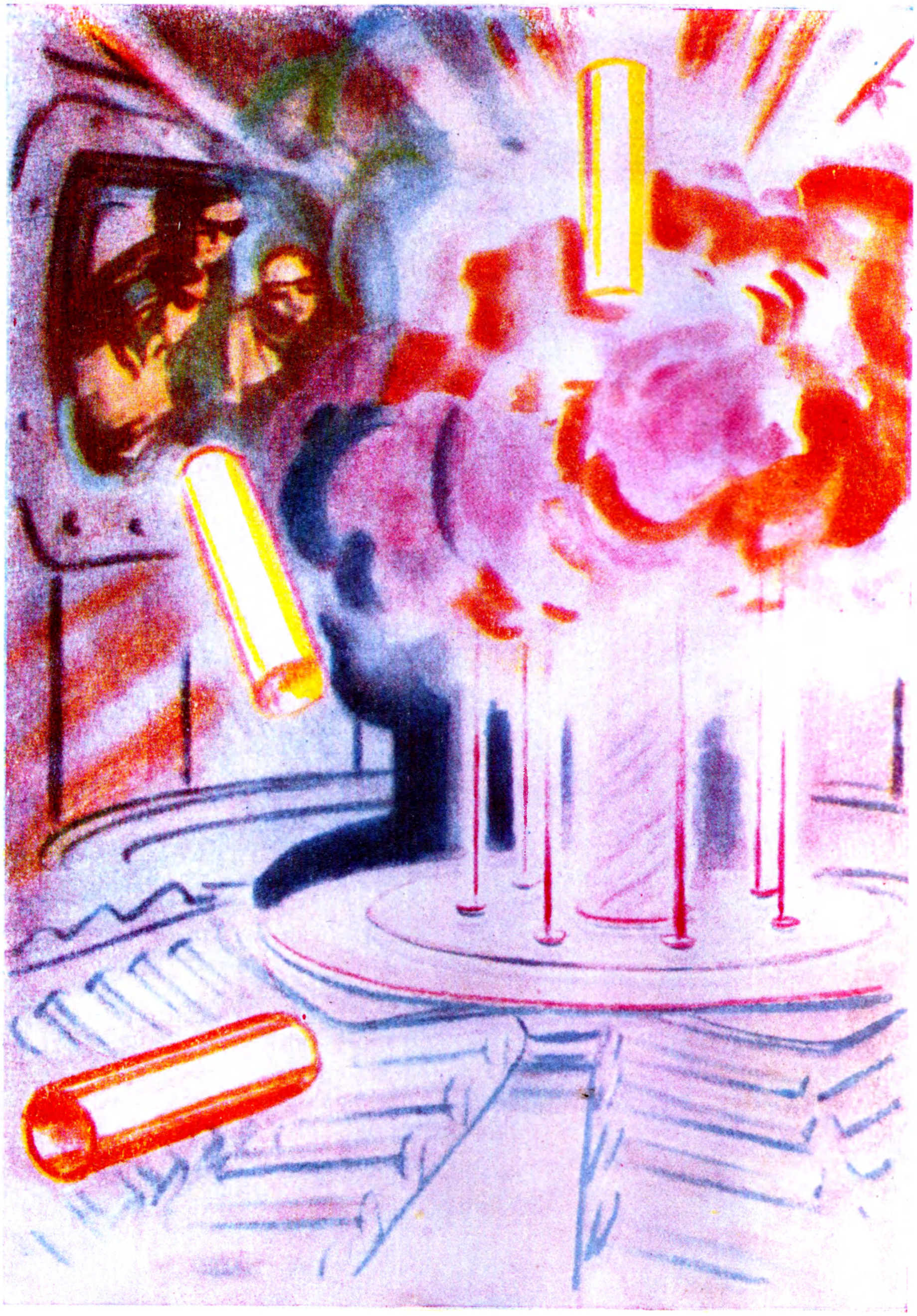
"It now takes several days or weeks to do the work for which even the heroes in folk legends required half a lifetime. A new mine was built in China, north of Lanchow, on December 31, 1956. More than 500 carloads of ammonium nitrate, i.e., 9,200 tons of explosive, bared an ore bed by removing a heavy layer of earth with one mighty blow and sped up the work by a whole year. This record-breaking constructive explosion was a complicated, subtle and grand affair.

"Today explosives and agricultural fertilizer are made from the same substances. Is it possible then that blasting engineering will develop at the expense of fertilizer? Will thousands of carloads of explosives go up in the air every year without ever becoming food for the plants?

"Of course, not. Here is the way it will be: a cylinder about 20 cm. in diameter will be lowered into an ordinary bore hole. The cylinder will contain a charge of thermonuclear substance replacing scores and even hundreds of thousands of tons of ordinary explosive. To place this amount of explosive underground would require vaults equivalent in volume to a couple of dozen eight-storey buildings. You can imagine how thermonuclear explosives simplify and expedite all the preparatory work.

"Take a look at a diagram of such an underground thermonuclear bomb. You will not recognize it. What has happened to the atomic bomb that plays the part of the fuse, the primer in a hydrogen bomb? Instead of it you see a strange device, a cumulative discharger. For a brief moment and in a tiny volume it creates such a concentration of energy (temperature) that it can set the thermonuclear reaction going.

"It is no mere accident that Artsimovich, the Soviet academician who per-



Parts of machines were born in the flames and roar of the tamed explosion. Nor could they have been manufactured any other way.

formed the first experiments with such an electric fuse, made use of the phenomenon of cumulation. Until very recently even the most daring fantasts could not imagine the astounding results the scientists, using the principle of cumulation, would achieve in our days.

"A concave mirror collects solar rays at one point—a focus. This is cumulation. Wood burns and metal melts in the focus of the mirror.

"Make this mirror out of metal emitting an electrical discharge of unprecedented power. The whole power of the explosion on the concave side of the mirror will be aimed at one point—the focus. This will be a cumulated—guided, concentrated—electrical explosion of enormous power. During the Patriotic War cumulative shells acting by means of ordinary explosives pierced the armour of tanks, which was sometimes several times as thick as the shell. An electrical explosion creates an even greater concentration of energy and acts as the fuse for the peaceful utilization of the power of explosion.

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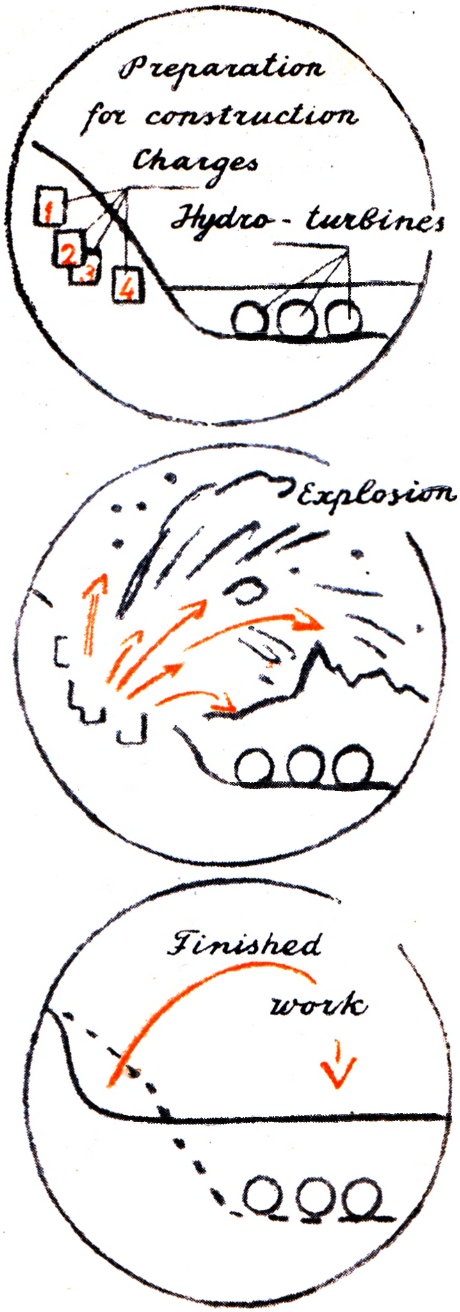


With such work organization the most labour-consuming stage—construction of an earthen dam—takes only a few seconds.

"The seeds of future engineering are abundantly scattered through the experiments performed by scientists today. For example, what is likely to happen if we explode a charge made in the shape of a cylinder? Something amazing will happen.

"Look," the professor takes a thick round pencil from his desk, "in such a pencil, if it is made of explosives, the power of the explosion will be directed not only outward, but, as a result of cumulation, also inward, to the axis of the cylinder, the lead of the pencil. The axis is transformed into a gun tube, as it were, and inside this tube the pressure instantly rises to enormous values. Streams of gases break out through both ends of the 'pencil' along the lead. If the whole charge, the whole cylinder made of explosives is exploded simultaneously these streams will travel at a supercosmic speed of 90 kilometres a second, which is three times as fast as the earth moves in world space and eight times as fast as the rocket that was recently sent on its interplanetary flight. I believe man will learn to use such speeds before the 21st century."

We all went to the laboratory.

"I bet you will never guess how this tube is made," said the professor and asked us to seat ourselves at a table on which we saw a steel pig that looked like a barrel of a small-calibre pistol with a narrow through bore.

A file rebounded from the metal which was martensite, a hard, high-carbon steel.

"Before the explosion," said the professor, "this was soft iron."

The professor tried to satisfy our curiosity as fully as possible. The pictures he painted amazed us no end. We took a mental trip to the 60th Anniversary of the October Metal-Working Plant. It was difficult, very difficult, to machine parts made of tungsten, molybdenum and other hard and refractory metals. They were hardly amenable to rolling. You could not make, say, a pipe from them. And yet no high-temperature atomic electric stations, nor light atomic aircraft engines could work without this simple part. Despite all the difficulties the 60th Anniversary of the October Plant manufactured such pipes. The pipes were made in a shop which pressed them by means of explosions.

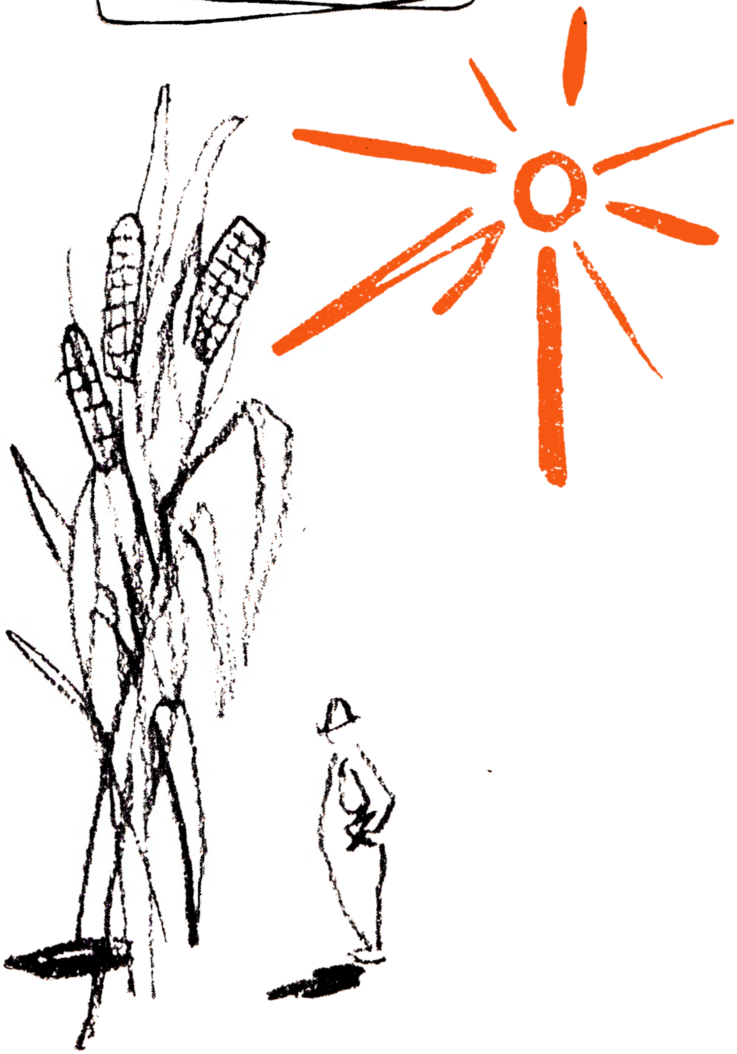
Explosions Rival Casting and Forging

The whole shop, when you entered, vibrated rhythmically. The conveyor fed a pipe made of explosive to a concrete chamber. On the inside the pipe was coated with an even film of fine tungsten powder. The chamber was closed. The operator pressed a button and an explosion followed.

At that moment the tungsten powder, thrown by the force of the explosion to the axis of the pipe, became cemented and pressed into a rod. By inertia the rod at first contracted, then as though growing elastic it expanded and a through canal was formed in it resembling the canal left in a pencil when its lead is taken out. In this form the tungsten pipes cooled. This powerful press, this machine in which the parts consisted of gas streams was operated by a youth with a Komsomol badge on his breast. We watched him change from time to time the size of the charge and the radii of the explosions. He was making tungsten pipes to order and they were of different sizes. Still hot they moved along the conveyor through the store of ready-made articles.

"These are but few examples of using explosions in the engineering of the future," said the professor. "There can be no doubt that the more man extends his power over nature, the more frequently he will resort, in most diverse cases, to explosions—this wonderful and as yet very largely unknown and unexplored form of instant transformation of energy."

IN THE NAME OF LIFE AND PLENTY



Biology Will Become an Exact Science

Tale About Bloodless Surgery

The Golden Age of Plenty Is Coming

At One Table with Poseidon

During one of our chats Academician A. Nesmeyanov said:

"You must not fail to speak to some physicians and learn about the prospects for the development of their science towards the 21st century. I think that by that time most of the terrible present-day diseases will be stamped out. In our time medicine has been making enormous progress. Was it so very long ago that pneumonia was a protracted and grave disease that not infrequently ended in death? And today it only takes a few shots of penicillin to put the sick person on his feet. The next question on the agenda is eradication of tuberculosis. As a matter of fact, about the only unconquered diseases are cancer, mental and cardiovascular diseases. But there can be no doubt that by the 21st century none of them will be any more dangerous than pneumonia is today. What will the physicians do then?

"I believe they will find prophylaxis, sanitation and hygiene alone rather tiresome. The physicians will then undoubtedly set themselves a new and extremely important task which they will never quite complete. They will work on perfecting the healthy human organism. They are doing it to some extent even now, since physical culture is a method of developing and perfecting the organism. But then it will be the main problem and will assume new and, from our point of view, wonderful and extensive forms.

"It is my personal opinion that in the long run it does not really matter whether a man can lift 70 or 80 pounds with his left arm as long as he is generally well and vigorous. And if, by any chance, he has to lift 300 pounds he can use a crane. It is not a question of developing the muscles endlessly. We must think about qualitative changes in the organism, for example, about perfecting our mental activity.

"See how very limited man's possibilities in this field are. A page a minute.... Don't you think this is too slow for reading? *The Life of Klim Samgin** is a wonderful novel but does it not take too long to read? We have to take notes at lectures and make files when working with scientific literature, since experience tells us it is somewhat risky to rely on the memory. But all this takes a lot of precious time which could be used for creative, constructive work. There can be no doubt that perfection

* A novel by M. Gorky.

and intensification of man's higher nervous activity is one of the most important problems of future medicine. To the person who solves this problem or at least suggests ways for its solution—because this problem will probably prove too much for one person—grateful humanity will erect monuments in all of the world's capitals."

All this was said with a smile and was hardly intended for the press, but it stimulated us to devote much more time to biological and medical problems than we had planned.

Science has a fighting front with its firing line and it is all along this line that science is attacking according to all the rules of the art of war. If we continue this simile we shall find deep encircling operations in which the enemy is attacked from different directions and the advance forces of the scientific attackers meet somewhere way behind the enemy's lines. We shall also find precipitate attacks of powerful detachments against stubbornly resisting fortresses, and regular sieges of certain fortified areas lasting for many decades. Nor is this war fought without retreats, for it happens that a daring hypothesis, which has broken through far into an unexplored area and has to all intents and purposes subdued it, finds itself utterly defeated and completely destroyed by the heavy artillery fire of new facts with which it cannot cope and which it cannot explain.

In our time, however, these are not general retreats and the scientific front invariably advances, although, like in real war, it does not advance evenly. Assault detachments break through here and there, and shock troops rush into the breaches, widen them and exploit the success.

At the points of breach the scientific front is making solid advances. But, as between neighbouring units at the front, in science there is also interaction between its various detachments. Success at one section of the scientific front helps the neighbouring and sometimes very distant sections to advance.

To be first in science means to be first precisely at the points where the breach is either planned or has already occurred.

In recent decades science has made enormous achievements. To begin with, we must mention the progress made in the physics of the atomic nucleus. This progress made the advances of so many seemingly widely separated sections of the general scientific front possible. Here we have biology—the method of radio-active tracers has enabled scientists considerably to extend our knowledge of metabolism in the vegetable organism; and medicine—the secrets of malignant tumours have become much less intricate since they have been studied with the aid of radio-active isotopes, and history—by analysing the isotopes scientists have been able to determine very accurately when the chariots of the Egyptian Pharaohs and the ships of the vikings were made. It would be difficult to enumerate all those new and important things that this advance—which is still far from finished—has brought about. Scientists keep extending and deepening this advance by studying in ever greater detail the structure and very essence of matter; they find ever new application for the regularities they discover and with their new knowledge approach ever new things.

The second such important advance has been made by the chemistry of plastics, the latter beginning to compete with metal in machine-building and with wood in construction; plastics are also invading ever new spheres of industry and everyday life.

Semi-conductors also constitute one of the most important advances made by science.

The launching of artificial satellites of the earth and the sun, the first heavenly bodies made by the hands of man, is likewise a major advance on the scientific front. It is as yet impossible to imagine what the acquaintance with the vegetation found on Mars may mean to biology or perhaps even to agriculture, or what geologists and metallurgists stand to gain from precise analyses of the rocks existing on the moon and Mercury. One thing is clear, and that is that this advance will tremendously affect the development of a very wide range of sciences.

To determine the most probable points of the future advances and issue a command to the scientific front to concentrate shock detachments for an offensive at these points, is a matter of great complexity and responsibility! In the Soviet Union these questions are studied by the U.S.S.R. Academy of Sciences and its Presidium.

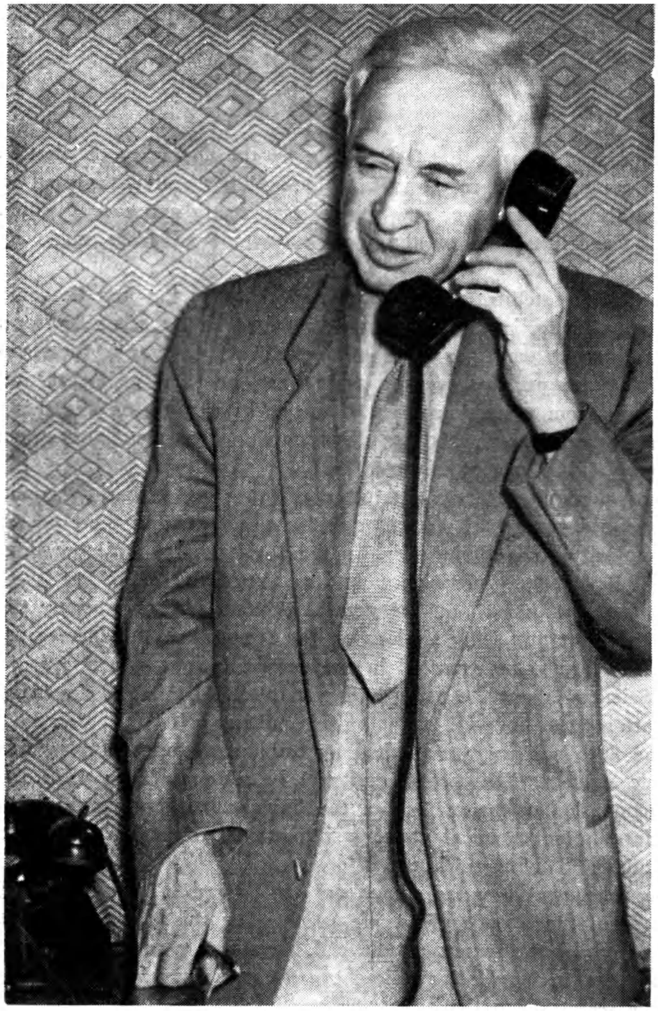
We have spoken to many scientists and the general opinion is that precisely the biological sciences are the most promising sections on the scientific front where great advances into the unknown are to be expected in the nearest future.

Biological sciences. Sciences about the living half of nature. To think of the many wonderful secrets they are soon to unravel!

The first half of the 20th century was marked by brilliant victories of physicists who stormed the atomic nucleus. The second half will in all probability yield the solution of the secrets concealed in the nucleus of the living cell. Physicists have already learned to transform some chemical elements into others. Biologists will learn to create protein molecules and living substance.

The secrets of living substance are attacked not only by biologists. Many scientists seemingly far removed from the science about life are joining this offensive. While biologists are trying to unravel the secrets of the cell, the nucleus and the protein molecule by analytical methods, by decomposition, organic chemistry is approaching the solution of the same secrets from the opposite direction, i.e., by synthesizing increasingly more complex molecules. While psychologists are endeavouring to gain an insight into the mechanism of thinking by studying the inborn and acquired reflexes, specialists in the field of automation are building logically acting mechanical and electronic devices and systems which have a "memory," are capable of simulating the behaviour of living beings and possess, as it were, inborn and acquired reflexes. The methods and achievements of other sciences are enriching biology and expediting its development. Biology, in a broad sense of the word, is undoubtedly one of the sections of the general scientific front which will make a revolutionary advance and on which brilliant victories will be scored during the coming fifty years.

In this chapter we shall tell the reader about our chats with several participants of this vast offensive.



Biology Will Become an Exact Science

During any period of scientific and technical progress some one branch of human knowledge always came to the fore. Thus the age of steam was replaced by the age of electricity, while within our memory chemistry has developed rapidly and atomic physics has advanced with seven-league strides. But what branch of human knowledge will take the lead in the 21st century?

"It is my profound conviction," said Academician Vladimir Engelhardt, "that it will be physico-chemical biology. There is hardly a substance in the

world whose structure an analytical chemist cannot decipher. Synthetic chemistry is enriching nature with new materials which it 'makes to order' with predetermined properties. Physics has penetrated into the innermost depths of the atom and has opened up for humanity unprecedented and inexhaustible sources of energy.

"In this precipitate advance the exact sciences have devoted their principal attention to inanimate nature. A momentous event is coming to pass before our very eyes: biology, the science about the living world, is becoming an exact science. This is happening as a result of the increasingly wider use of the methods of research adopted by the exact sciences—physics, chemistry and mathematics—in studying living objects.

"Human life extension has been the most cherished dream of many generations. We are steadily approaching this aim, although perhaps not so fast as we should like to, the average life expectancy having increased at least by 20 years during the life of one generation as a result of the fact that we have almost eradicated the most important infectious diseases caused by bacteria (croupous pneumonia, typhus, typhoid fever, malaria and tuberculosis). The discovery of the nature of cancer is the greatest achievement we are justified in expecting from science in the nearest future. As soon as the peculiarities of the chemical processes occurring in the cancerous growth and distinguishing the healthy from the diseased tissues are ascertained, it will be possible to consider ways and means of controlling this dreadful scourge of mankind.

Cancer Will Be Vanquished

"Scientists are already trying to figure out how long it will take them to do this. Even the most cautious of them set the time as at most two decades. If these forecasts come true, it will not be fifty years before man begins to forget the scourge of cancer as he is now forgetting that of smallpox and hydrophobia.

"It is hard to say who will have greater chances for success in this fight against cancer—the chemists with their drugs or the physicists with their means of radio-active influence. It is possible that victory will be ensured by the concerted offensive of the two sciences.

"Let us imagine that chemists have discovered the substances which are accumulated in the tissues of the tumour and are retained by it as by a filter. If such a tumour is irradiated with a beam of neutrons harmless to the healthy tissue, the substance accumulated in the tumour will become radioactive. Irradiation from within will destroy the tumour without harming the human organism.

"Eradication of diseases will greatly extend human life. But we have another interesting possibility. We spend one-third of our lives sleeping, thus wasting the time we could use for ourselves and society.

"During sleep the substance of the nerve cells is restored, and the nervous system is, as it were, recharged. The products of activity of the nerve cells, which may be conditionally referred to as fatigue toxins, are neutralized.

"Phenamine, benzedrine and other preparations delaying the onset of nervous fatigue for a rather long time and making it possible to keep awake two or three times as long as usual were synthesized during the war. To be sure, this 'economized' sleep had to be made up for later by much longer sleep.

"After ascertaining the nature of the 'fatigue substances' and the ways in which they are formed chemists will find methods of either rendering these substances harmless by the action of enzymes or binding them by chemically harmless drugs.

Internal Longevity Reserves

"But we can also conceive of other ways of 'removing' fatigue. Let us imagine, for example, that scientists will find such forms of electric oscillations which, led through tiny electrodes applied to the head, will penetrate into the brain and accelerate the processes of restoration operating in it. The fatigue toxins usually neutralized in eight hours of sleep will be rendered harmless without any damage to the organism in one or two hours. To shorten sleep in this manner, means to add 20 or 30 years to man's active life by using his 'internal reserves.'

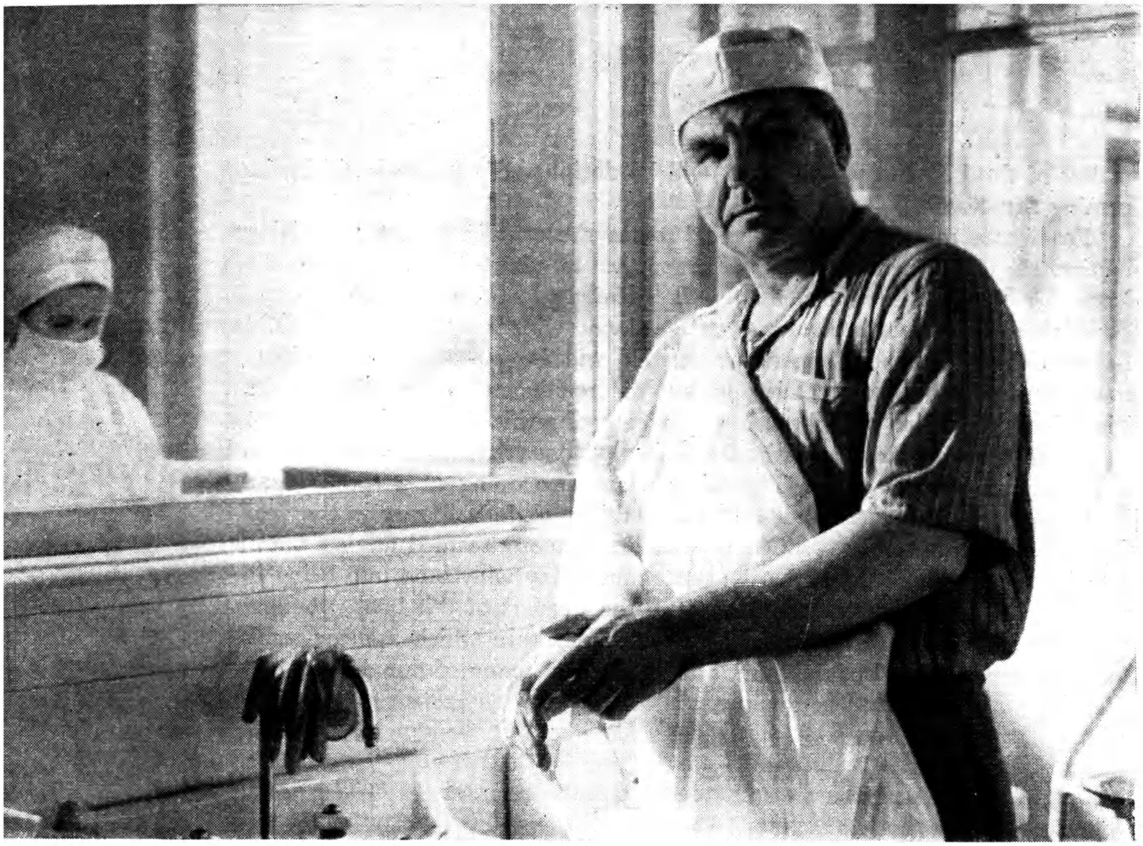
"The hardest riddle in modern biology is that of heredity. It is the question of how a single microscopic cell contains the innumerable details of the structure and function of all the organs and tissues, the characteristic properties of the future adult organism, and combines in the embryo the traits of the parents, the 'hereditary information' transmitted to the offspring.

"The naive ideas of vitalists that some mysterious and unknowable vital forces operate in organisms have long since receded into the past. In the course of our century biologists have ascertained in detail the general laws of heredity. They are now coming ever closer to the final ascertainment of the nature of the substances that transmit this 'hereditary information.' To decipher the language of the atomic and molecular combinations by means of which this 'information' is translated into a chemical and physical code, is the job of future biochemistry. It is an uncommonly hard job, and we must not be unreasonably optimistic to believe that the 'biological code,' the chemical

cipher of the hereditary properties, will be deciphered and read within the coming fifty years.

"From that moment on man will become the complete master of living nature. He will impart such useful properties to plants and animals as the latter, by obeying the will of man, will reproduce in the subsequent generations. We have already made some headway with simplest organisms. I believe that by means of 'genetic poisons' it will be possible to exterminate many forms of pathogenic microbes or to 're-educate' them, if you will. Biologists will render them harmless by means of artificial mutation.

"Of all the foregoing fantasies there is not one that does not rest on achievements already made. The sciences are developing at a speed of an avalanche, and it may be that on finding this book in a library in the year 2010 some scientist will say: 'Oh, how modestly they dreamed at that time!' I believe some of the things I told you about today will come into being in my lifetime. I am certain that many of the readers of this book, younger than I, will not only live to see the wonderful future which appears semi-fantastic to us today, but that they will even carry many of our dreams into life."



Tale About Bloodless Surgery

It was an amazing surgical clinic and the day we spent in it could be described in a separate book.

Mikhail Ananyev, the director of the Institute of Experimental Surgical Apparatus and Instruments, who showed us around this ordinary clinic of the near future tiptoed to the door of one of the rooms and opened it. The patient nodded to us to come in. With a customary movement he dropped his arm on a tiny panel at his bed and turned the radio off. He pushed another button and the head of his bed rose so that he could talk comfortably in a reclining position. Not only the construction of the bed was unusual though; unusual also was the fact that, while in bed, the

patient could raise the blinds on the windows, turn on the lights, ventilation, etc.

In the next room we saw a woman in a white robe sitting at a panel. Before her there was a couple of dozen TV screens. We must have looked puzzled because Ananyev hastened to explain:

"She is the physician on duty. She is watching all the grave cases and is ready to send a physician or nurse to their aid at any moment. Electrical thermometers and pulsimeters keep recording the patients' temperature and pulse."

At the Panel of the Physician on Duty

But all these apparatus proved very simple compared with what we saw in the diagnostics room.

"Stethoscope," said the professor glancing at wires running from the bare chest of the patient to the loudspeaker on the desk.

We searched in vain for the customary instrument with its black rubber ear-pieces which usually disappear somewhere in the physician's ears.

"Radiostethoscope," the professor hastened to correct himself.

The loudspeaker emitted strange squelching sounds. It was the blood running through living pump—the man's heart—and the diagnostician listened to each movement of its muscles as a musician listens to the beats of a metronome.

We looked about.

"Diagnosis" was the word we read on a device standing, like a glass bookcase, against the wall.

"Please, turn the electronic computer on," said the professor to a diagnostician.

The latter put the patient on a couch, into a hollow that was made to fit the human body, and quickly connected the leads to his arms, legs and neck. Indicator lamps began to flash and relay switches to click. The machine "pondered" over the patient's pulse rate, his respiration, blood pressure and blood test data fed into the electronic device beforehand, and many other indices which even an experienced diagnostician cannot all at once perceive and take into consideration. The decision was unexpected. The machine simultaneously named three diseases with queer Latin names. It seemed to say: "I have rejected scores of thousands of possibilities. The signs you gave me are encountered in all these three very similar diseases. There is nothing else I can do. You will have to decide on one of these three yourselves."

Machine Diagnoses Disease

"Turn the radio-locator on," our guide advised the physician.

The screen showed the outlines of the heart, liver, stomach, intestines, etc. The device determined all the deviations from the normal size and location of the organs with an accuracy of up to one millimetre. Examination with the radio-locator was made possible by the fact that each organ has a different density.

Only ten minutes had elapsed and the physicians already knew that the patient had a rare disease which formerly took a long time to diagnose.

But it is one thing to diagnose a disease and quite another to cure the patient. We asked to see the operating-room and the scientist took us to the adjacent room.

"You must have made a mistake, Professor," we said. "This is a physiotherapeutic rather than an operating-room. There is only electric apparatus here, not even an operating-table."

On a couch there was a patient. Over the patient there was a softly droning apparatus. No surgeon or blood-soaked tampons were anywhere to be seen. And, as though this was quite the usual thing, the director began to explain and only now and then cast a sly glance at us for he was certainly aware of the astounding impression his words were making on us.

"This is an operation on the liver," he said. "You see stones being removed from it."

We were all eyes but could not see anything and, winking at each other, we decided to play up to the professor.

"Wonderful, Professor," we said. "Just think of it: remove the stones from the liver and never even touch the patient with either hand or knife. Technique bordering on fantasy. . . ."

"Precisely," the scientist continued. "It takes ultrasound 20 minutes to crush the stones to a fine sand. Within a few days the sand will be excreted from the organism through the digestive tract."

Knifeless Surgeon

"But what about. . . ?" we began and immediately fell silent. We wanted to ask if the soft tissues may not perchance be damaged by the ultrasonic stone crusher. How could we possibly have forgotten that the oscillations of ultrasound only lightly heat the soft elastic tissues, whereas solid bodies, for example stones, break up from the frequent ultrasonic oscillations even if they are buried deep in the body. Why, there was no fantasy there at all!

"As you see," the professor went on, "it is possible to cure a person without cutting him. This is what an ideal operation should be like. Today we are making very wide use of the power of inaudible sound. You will see how

The heart did not interfere with the work of those who were busy repairing it.

teeth are drilled in our clinic with a dentist's ultradrill, an instrument for treating the bones. But you probably know all this, since ultrasonic techniques were used before, although not on so large a scale, of course, as they are now. And now let us take a look into another operating-room."

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The professor asked us to change our shoes for sterile rubber slippers, put on gauze masks and follow him into the operating-room. At last we saw a typical operating-room of the middle of the 20th century. True, the operating-table had changed and had become more convenient. It was no longer lowered and raised manually, by turning various handles; all you had to do now was to push buttons. To be sure, the lamps were also different. They were bactericidal. They not only lighted the room but also killed the pathogenic microbes with their light. The room was, of course, spotlessly clean and air-conditioned.

But why was there a TV screen over the table, in front of the surgeon?

"This is not an ordinary TV set," the scientist explained even before we chanced to ask a question. "It is connected with an X-ray machine. An X-ray image can be seen only in the dark, but we have transferred it to the bright TV screen. Look! Here is that sharp hook in the child's stomach. The little one swallowed it in play. Everything will be all right, though. The surgeon will be on the right track the moment he starts the operation; on the screen he will see his own hands and the distance he has to cut to reach the target. Incidentally, he does not need the knife any more...."

We were taken aback. Cut without a knife?

"Why, yes. I have already told you we have given up many of the former methods of surgical intervention. Quiet, please...."

Seeing that we were whispering the surgeon, who was to perform the operation, shook his head disapprovingly.

"Anaesthesia...."

The electric anaesthesia apparatus hummed softly. The pulsating electric current lulled the child's brain. Several minutes later the surgeon said:

"Well, now we can talk aloud. The patient will not wake up until we turn the apparatus off. It is a remarkable device. No pain sensations at all. Do you remember how we used to torture patients with chloroform? Of course, we put them to sleep, but how terribly bad they felt after the operation. We also operated under local anaesthesia, made a novocaine block, anaesthetized only the place to be operated, 'disconnecting' this place from the whole

nervous system. Electric anaesthesia has grown out of the treatment by electric sleep of which I. Pavlov dreamed.

"Let us begin," the surgeon nodded to the chief nurse.

The students who had come to see the operation went into the adjacent room. They would see the operation in every detail on a special large TV screen built into a tile wall. The operation would be accompanied by a lecture. The students would not have to "hang" over the surgeon, to peep over his shoulders.

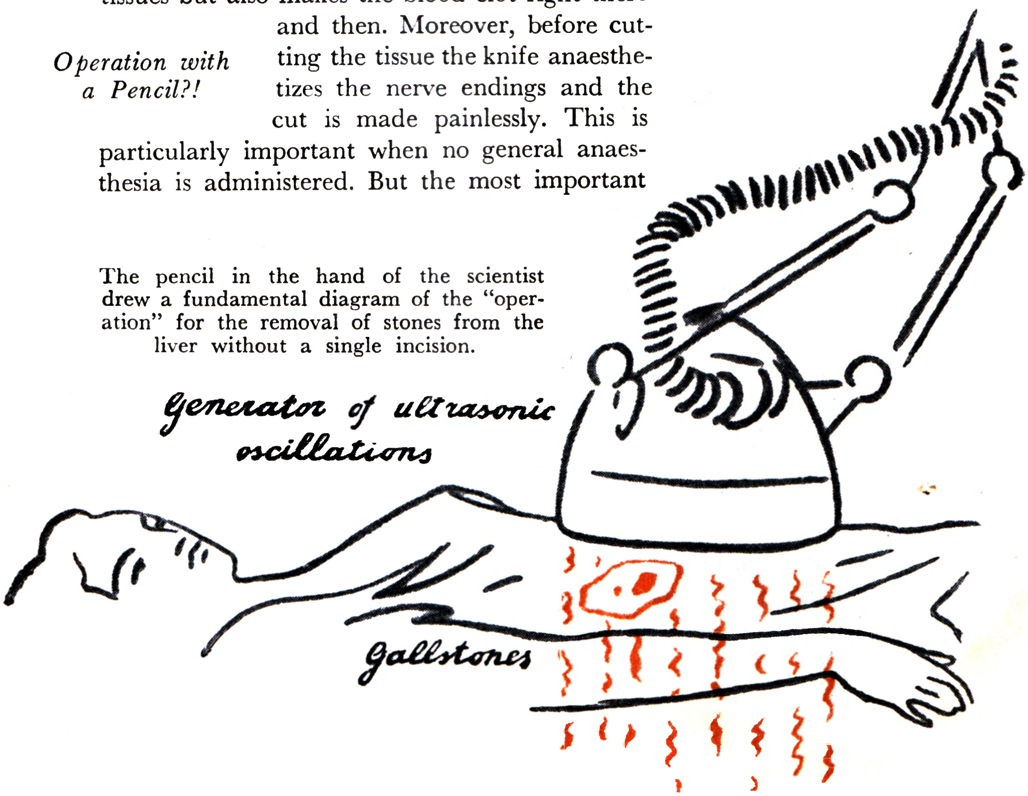
The surgeon picked up something that looked like a large pointed pencil. From the blunt end of the pencil a wire ran over the surgeon's shoulder.

If we had not seen it with our own eyes, not a single scientist, nor a single science fiction writer, could make us believe in this miracle. When the surgeon slowly drew the "pencil" along the skin of the person being operated an even cut appeared on the body. Then the viscera showed themselves and yet not a single drop of blood was to be seen along the edges of the cut.

The ultrasonic knife with which the surgeon operated made the operation bloodless. It happens that ultrasound of a certain frequency not only cuts tissues but also makes the blood clot right there and then. Moreover, before cutting the tissue the knife anaesthetizes the nerve endings and the cut is made painlessly. This is particularly important when no general anaesthesia is administered. But the most important

Operation with a Pencil?!

The pencil in the hand of the scientist drew a fundamental diagram of the "operation" for the removal of stones from the liver without a single incision.



thing is that the knife is always sterile, for the ultrasound kills the microbes right in the wound.

We looked with veneration at this surgeon-magician who held in his hand the magic electric wand—the ideal knife that cut bloodlessly, painlessly and sterilely.

The stomach had to be opened for the sharp hook stuck in its wall to be removed. We expected to see a needle and silk thread used in ordinary operations. But it all turned out differently.

"Glue!" the surgeon said curtly.

The cut edges of the stomach were brought together and a mushroom, like the one on which socks are darned, was placed under them. A strip of adhesive transparent film was placed on the cut and the stomach was ... glued.

"But don't think glueing completely replaces the suturing of wounds," the professor warned us. "If need be, we have at our disposal a thin tantalum thread, which is absolutely harmless for the organism, and threads made of fibrin and blood serum—substances akin to the human organism. Such organic thread keeps the seam intact as long as it takes the wound to heal. Then it dissolves and disappears without leaving a trace.

"A stainless steel nail can be driven into a broken human femur or humerus. The bone set on such a 'spit' heals properly and rapidly. And only an X-ray machine will show that a foreign body—the steel nail—is still in the bone. But if such a 'nail' is made of fibrin or blood serum, by the time the bone has fully knitted (i.e., not later than in six months) the nail will disappear without leaving a trace.

"You saw the effective action of surgical glue. It is an amazing thing."

*

There was only one patient in the room we entered. To all appearances he was particularly well taken care of.

"Serious case of poisoning," said the scientist. "He would undoubtedly have died if it had not been for artificial kidneys. It is a matter of regret, however, that these kidneys are a bit too large."

The thing, the scientist was referring to, looked like a glass night-table. It stood near the patient's bed, several thin tubes connected to the patient. The patient's blood ran through chemical filters of the apparatus where the urinary slags were removed and the blood was enriched with the necessary

substances. The patient did not even know that his own kidneys were not functioning.

The professor told us that by this method it was possible to cure grave kidney diseases and prevent the death of a person from poisoning by his own urine. It was also possible to transplant normal kidneys taken from a deceased person.

Something unusual was happening all around us.

"Come and let me show you an artificial heart. Here it is," the professor pointed through an open door at a cabinet the size of a bookcase.

Nurse, Stop the Heart, Please

The cabinet was working. Automatic electric devices maintained the assigned regime of three litres of blood per minute, a pulse of 80 and a pressure of 120. The moment the pressure in the organism dropped the automatic device began to pump more blood.

The voice of the surgeon in the adjacent room suddenly broke the silence.

"Nurse, stop the heart, please. And make it snappy, it hinders my. . . ."

We felt ill at ease. To think of the grief experienced by people when the heart of the one they love and cherish stops! Physicians do all they can to prevent it from stopping. And here. . . .

The surgeon calmly drained the blood from the arrested heart and began to operate on it. The heart disconnected from the organism did not stir. But to make up for it, the "spare" mechanical heart in the white glass-case beat regularly, pumping blood through the tubes into the aorta.

It is very hard to sew up a wound in a pulsating heart with a needle. The operation neared its end. The surgeon was tired, his hands in particular. Automatic and semi-automatic machines for suturing blood vessels and tissues were therefore invaluably helpful. The surgeon held the machine in his hand and put the ends of the vessel into it. Click . . . and the vessel was sutured. It took but an instant. Formerly it took 30-40 minutes. Another "sewing" apparatus was brought close to the heart. An instant and the wound was sewn up.

The surgeon straightened up and ordered, "Turn the heart on, please."

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The "repaired" heart was full of blood again. But this time it had adrenalin in solution, the substance that would stimulate the nerves of the heart muscle and would force the heart to make the first beat.

The heart was beating faster and faster. The surgeon who had already

taken the glove off his left hand suddenly stood stock-still. The heartbeats now resembled a light quiver. It was no longer possible to distinguish the separate beats, nor could the pulse be palpated. The heart rate rose to 200 and then 300 beats per minute. It was throbbing. Physicians call this condition "fibrillation." It always precedes complete arrest of the heart, its real death.

Without waiting for further orders the nurse handed the surgeon a metal object that looked like a punch with a handle. It was an electro-defibrillator. As soon as it touched the body the surgeon turned on the switch. A tiny lightning, an electric discharge pierced the chest, went through the heart and made it contract. The next moment the heart relaxed and then began to beat regularly and normally.

Then another electrical apparatus was turned on. This device was designed to watch and regulate the cardiac and pulmonary rhythm.

The operation did not last an hour, as we expected, but only 15 minutes. We learned that the artificial heart helped to return to life scores of people who were in a state of clinical death. It brought relief to hundreds of people when their hearts began to fail.

But let us go back to operations.

It is not at all immaterial to the patient whether he is kept on the operating-table 5 minutes or half-an-hour. Mechanization of the complex and labour-consuming operations in medicine not only expedites the surgeon's work but also makes it more reliable. An automatic machine operates equally well in the hands of a virtuoso surgeon and an ordinary surgeon.

M. Ananyev told us about the automatic devices invented in the middle of the 20th century. It seems automatic machines which sew up all manner of blood vessels have been in existence for a long time.

Special devices instantly tie off blood vessels and bronchi. This reduces the operating time by about four-fifths. The pleura, peritoneum, skin, stomach—a special automatic apparatus is used for sewing up each type of tissue.

People have learned to inosculate nerves and blood vessels and to knit bones and other body tissues. Then it should not be difficult to graft, for example, a severed arm or leg?!

"Of course, not," surgeons say. "Let us have the arm or leg and we shall immediately restore them to their owners.

"Such operations became the usual thing about the 1950s. Today surgery is becoming restorative. If your knee joint is damaged we can remove it and replace it with a new one made of plastics. Of course, we shall impart the

requisite shape to it. In injuries and tuberculosis, or if a joint is developing improperly and is painful, we can easily replace it.

"In the 19th century people joked: 'Take care of your limbs because god did not take the trouble to make spare parts for the human body.' But we, physicians, have now created such 'spare parts.'

"It sometimes happens that a portion of a vessel 10-15 cm. long has serious defects. We remove this portion and replace it with a tube made of nylon or capron. There is also another method: part of the vessels of a deceased person we preserve in his own blood. In a refrigerator these vessels can keep for a very long time. But if such 'spare parts' are placed in a vacuum and then kept at —60° C, they can keep endlessly. This method has long been used in clinics and institutes. But it is no longer a prosthesis; it is a transplantation of vessels.

"We can speak about transplantation endlessly. An interesting experiment was performed as far back as the first half of the 20th century. We performed a nephrectomy on a dog, i.e., we excised its kidneys, and then grafted one of them in another place—on its neck. We brought the dog's ureter to the exterior and the dog remained well as if nothing had happened.

"Any transplantation is safe as long as we transplant organs and tissues taken from the same organism (so-called autotransplantation). But the picture changes when we begin a homotransplantation, i.e., a transfer of organs from one organism to another.

"Soviet surgeons excised a dog's heart and transplanted a heart of another dog to it as far back as the 1940s. The animal with a foreign heart lived 8-10 days and then suddenly died.

"Why? This question tormented biologists and physicians for a long time.

"Our techniques are so perfect that surgeon V. Demikhov ventured to transplant the head of one pup to another pup as early as 1956. The 'foreign' head lived on the other dog's neck for six or seven days. It saw and heard everything, smelled odours, reached for food and lapped milk. Then it died.

"Why do transplanted kidneys, lungs and other organs die?

"By 1957 we had solved all the technical questions of transplantation, save the principal one," said Ananyev. "It is the question of the biological compatibility of organs and tissues.

"A human being will die if the blood of another person belonging to a different group is transfused to him. He will live if he is given blood of the requisite group. There are four such groups.

"Physicians know all the rules of safe blood transfusion because they have discovered the law of biological compatibility of blood. However, they have

as yet been unable to discover the laws of biological compatibility of the other tissues and organs.

"A person has suffered a burn and foreign skin is transplanted to him. Do you think this skin is grafted for ever? No, it is not. It serves only as a 'carcass' along which new skin is grown. As soon as new skin has grown under it, the organism rejects and throws the foreign skin off, and the foreign skin dies.

"It is as yet impossible to transplant organs taken either from brothers and sisters or from parents and children. Only once did the scientists of the 20th century have luck: the kidney transplanted from one twin to another took root. This singular case was studied very thoroughly. The scientists performed new experiments and gradually began to discover the laws of biological compatibility for various organs and tissues. Think of the famous experiments of Professor Filatov transplanting the cornea. It sufficed to keep the cornea taken from a deceased person in the cold a little longer and the biological incompatibility disappeared. But it was impossible to transplant a fresh cornea.

"We have now just about solved the problem of biological incompatibility. As soon as this problem is solved we shall make use of all the technical means we have accumulated. We shall be able to take for transplantation any part of the body of prematurely deceased people. If it were not for an accidental injury any organ might serve twice as long as the longest life.

"Somewhere in the Sklifosovsky* First Aid Institute we shall probably see the following picture: the bodies of recently deceased people will be kept in refrigerators. Artificial circulation of the blood will be maintained in these bodies. Figuratively speaking these will be 'living corpses.'

"At any time at all a surgeon will be able to take from this store of spare human parts any organ and transplant it to an injured living person. I think that at first we shall be able to transplant limbs.

"The dead will thus help the living....

"What's wrong, young lady?"

Professor Ananyev jumped up and was bustling about our Tamara, the young stenographer who suddenly turned pale, closed her eyes and dropped her head on the desk.

She had fainted. Fascinated, we had completely forgotten that a girl who had probably never been inside an operating-room and had never seen any

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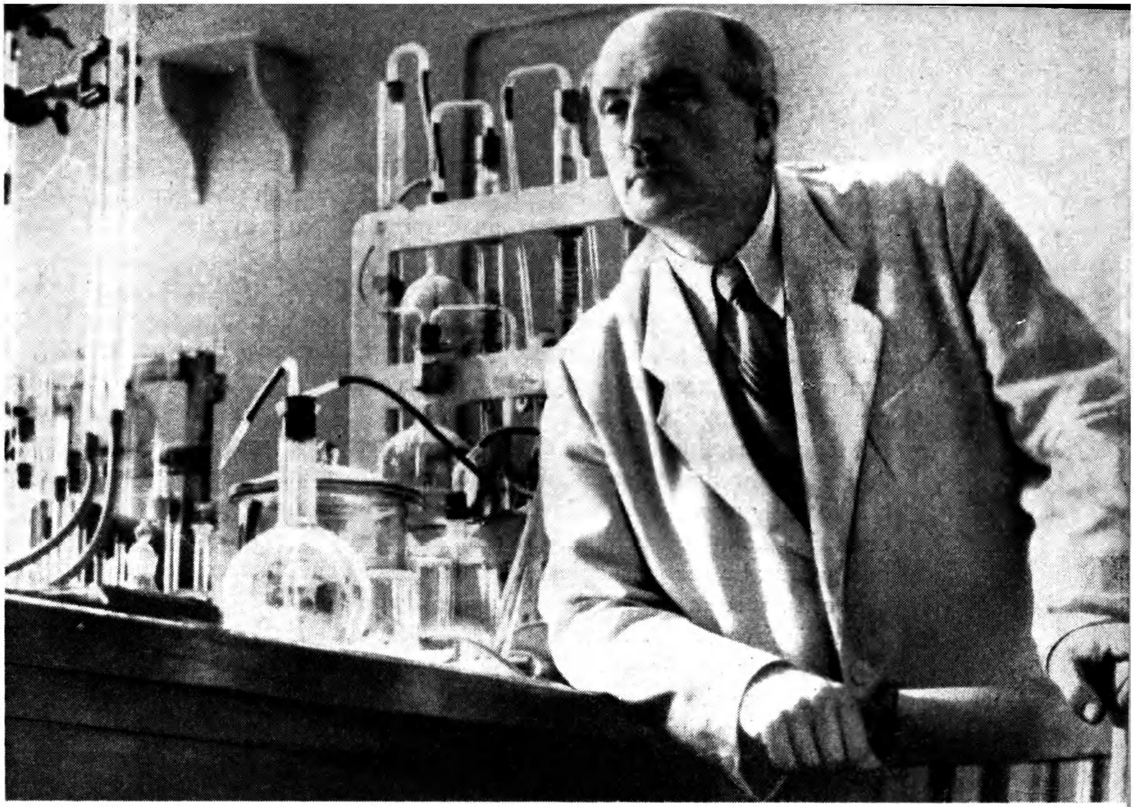
* N. Sklifosovsky (1836-1904), prominent Russian surgeon.

blood or corpses was carefully listening to us and taking down our conversation. We came back to 1960 and brought her round.

The girl felt better, she regained her colour, and we did not go back to the "dangerous" details and pictures any more. Professor Ananyev spoke about the great and humane profession of a physician and compared him with a conductor of a large orchestra in which there are many complex instruments and which renders beautiful and complex compositions but is conducted not by an automatic device but by a human being, only a human being. This was his answer to our question about the possibility of automating operations.

"Of course, this is only a comparison, a figure of speech," said the professor. "But having to do with complex machines everyone of our physicians is also actually becoming an engineer. A medical engineer. Where have you ever heard of such an occupation? It has just come into being, but it will inevitably develop and serve humanity in the 21st century."

We thanked the director and departed.



The Golden Age of Plenty Is Coming

"Couldn't you tell us," we asked Academician Semyon Volfkovich, "how many people our planet could feed? Is there any limit, in this respect, to the increase in population?"

"There is no such limit, nor can there be any," the academician answered confidently and without hesitation.

It seems he pondered this question many a time.

"Remember," said the academician, "more than 50 years ago Dmitry Mendeleyev believed that not only 10,000 million but even many more people could find means of subsistence on the earth if they were resourceful and worked hard enough. This was said early in the 20th century when the population of the earth numbered some 1,600 million. In 50 years the population has increased by nearly 1,000 million."

Where then does the food for increasing humanity come from?

In addition to the natural processes which nourish the plants, specially produced chemical agents play an important part in the circulation of organic substances.

During the Great Patriotic War the lands of Central Asia lacked nitrogenous and phosphatic fertilizer. In only three years the cotton crops on these unfertilized lands decreased 50 per cent. And now they produce 20-24 and even more tons of cotton per hectare again instead of the 10 tons they produced during the war.

Modern chemistry and the chemical industry are disproving the Malthusian "theory" as well as the pessimistic theory of "diminishing fertility" which was but recently regarded as a law. The agricultural practice of a number of countries shows that one-half the crop increase is determined by the fertilizer, one-quarter by the mechanical land tillage and one-quarter by the quality of the seeds. It seems like plain arithmetic, doesn't it?

K. Timiryazev, D. Pryanishnikov and other scientists calculated that by using organic and mineral fertilizer it was possible to raise the productivity of agriculture six- or sevenfold and by extending the sown area even 12- or 14-fold. Basing himself on the analysis of the increase in the population of the Soviet Union and the prospects for raising the crop yield D. Pryanishnikov concluded in 1925 that Russia did not have to worry about any food shortages for 150 years to come even if her population doubled every 50 years.

This remarkable forecast of the scientist who looked way ahead, into the 21st century, denotes the great power of science and engineering of which mankind is not as yet taking full advantage.

Several decades have elapsed since these forecasts. During this time biology and chemistry have made new advances.

If we considered the social progress and the new data, we could double or even treble the figures mentioned in Mendeleyev's forecast, i.e., if the achievements of science and engineering were widely utilized the world could provide food for 20,000 million or even 30,000 million people. But....

"You can imagine," said the academician, "what well-being all countries in the world could attain if they stopped squandering their resources on the armament race and used them for peaceful construction. I think that man's 'golden age' is not behind us but is yet to come. It will come when science used only for peaceful purposes permeates and transforms all of man's economic and cultural life."

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Chemistry will play a very important role in the future. The ability to isolate and bind the nitrogen contained in the air and the production of synthetic nitrogenous fertilizer constituted the greatest achievement of chemists in the 20th century. This required many years of persistent work on the part of physical chemists and engineers and great efforts of the industry which manufactured complex machinery from special grades of steel. Of tremendous importance are also the numerous new preparations for the protection of plants from insects, rodents and diseases, for the extermination of weeds, and for expediting and regulating the growth and yield of plants and animals. DDT, hexachloride, thiophos and other substances are much more effective and less harmful to man than the former pesticides—arsenate, fluoric, sulphuric, etc.

Microelements—the Vitamins for the Plants

We have grown accustomed to mineral fertilizer and chemical means of plant protection to such an extent that we forget they have been in existence but a relatively short time, the production of phosphatic fertilizer having begun only 100 years ago, potassic fertilizer about 80 years ago and synthetic nitrogenous fertilizer about 50 years ago. The problem of mass fertilizer production was solved in our century. New varieties of fertilizer are being continuously developed. Microelements which play about the same role in plant-growing as vitamins and hormones do in the human organism are now being extensively studied and introduced into agricultural practice. Some microelements are simultaneously plant disease remedies, boron curing beets from beet rot and flax from bacteriosis. Microelements added to fodder prevent a number of cattle diseases, copper preventing the licking disease and cobalt—tabes. This shows how very important even extremely small additions of these elements are.

We can safely predict that with the aid of enriched and medicated food the animals will, like man, be protected in the future from diseases and parasites.

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To get a picture of the future we do not necessarily have to build fantastic conjectures. You walk along the streets of Moscow and see big adult trees being planted in the ground. Formerly they usually struck root with great difficulty and ailed for a long time. But why do these trees take root faster and better now?

They do so because their roots are treated with special substances—growth stimulators.

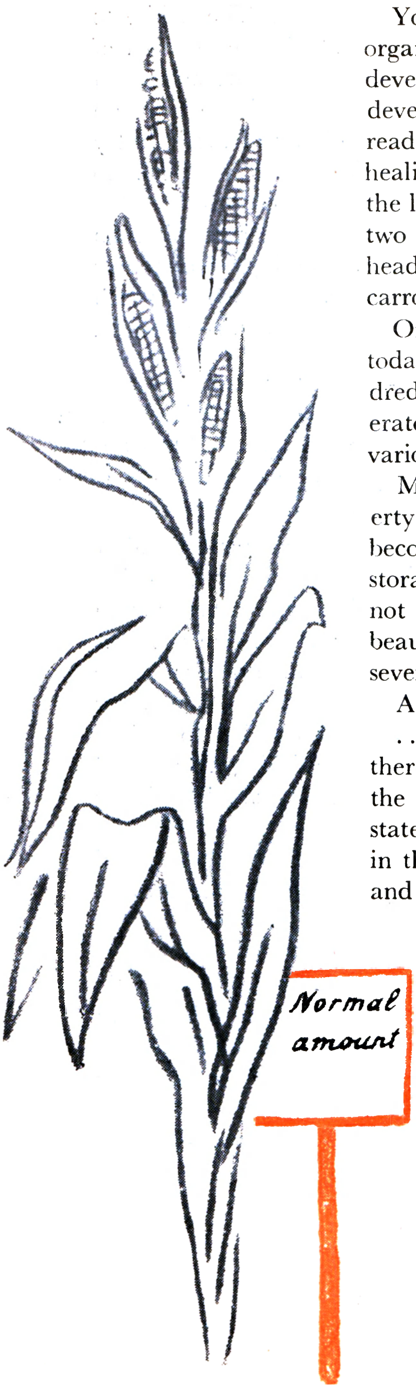
You take only a fraction of a gramme of a certain organic substance and the root system of the plant develops rapidly. Growth stimulators for the rapid development of tomatoes, apples and pears are already being used. Growth stimulators accelerate the healing of wounds on trees and remove, as they say, the limits to growth. They make it possible to produce two potato crops a year and to grow, for example, heads of cabbage more than a metre in diameter and carrots a metre long.

Only a few accelerator substances are being used today. Before long there will be scores and even hundreds of them. Scientists will find accelerators, decelerators and other regulators of vital processes for various species of plants.

Many growth stimulators have a wonderful property. If too large a dose of the stimulator is used it becomes a "decelerator." In such cases it prevents storage potatoes from sprouting for a long time, does not let unripe fruit fall off trees and even makes the beautiful rose, the joy of all flower lovers, blossom for several weeks rather than days.

And here are a few cursory pictures of the future.

. . . Autumn. Below, under the wing of the plane there are thousands of hectares of ripe wheat and in the centre a variegated rectangular carpet. It is a state farm buried amid orchards. Whence this oasis in this semi-desert? What gave the wheat, apple-trees and oak-groves the strength to rise on this barren



Everything in moderation! This truism can be demonstrated by the experiment shown in this picture.

Effect of stimulator

ground where formerly only sparse camel bur had grown? Chemical agents nourish the soil and improve its structure, produce rain and freshen the salt water of lakes and seas.

Artificial Snowfall

. . . It is freezing. It is cold for the winter crop. It has long been yearning for a nice and fluffy snow blanket. But there is no snow. A thin film of ice covers the pools of water and clouds are sailing low over the ground.

The flier pilots the plane into one of the clouds and turns on the sprayer. Crystals of carbon dioxide seem to give the cloud a sort of "stimulus" and the "seeded" cloud gradually melts and fluffy snow begins to fall.

Severe frosts were expected and an agronomist asked the flier to cover the winter crop with a blanket of snow. The flier waits for a cloud to overcast the sky over the crop or to be moved there by meteorologists and then produces a snowfall.

In the 21st century even childern will know that snow can be produced in winter and rain in summer. They will know that the powder poured out on the cloud by the flier evaporates and that a lot of heat is absorbed at the same time. The mist and steam in the cloud are supercooled and condensed, and precipitate over the fields in drops of water or snowflakes.

One summer night a frost suddenly occurred and the entire crop was in danger of freezing. The state farm had such vast fields that they could not possibly be heated with fires; nor was there enough time to transport smoke-pots to all fields. The state farm helicopters—the large transport helicopter and the small passenger ones—took up the fight against the frost and scattered smoke-pots over the fields. The smoke drifting along the ground saved the crop.

Trees do not easily acclimate themselves to deserts. The sands have but little nutrient and moisture binding and retaining substances. Chemists are beginning to treat sands and other soils which do not have the structure required for agriculture with structure-forming substances. Some organic substances are structure-forming. They can be produced from brown coal, wood, petroleum hydrocarbons and seaweeds. These preparations will be used in relatively small quantities. They will considerably increase the moisture capacity of the soil and will help to retain the nutrient substances in its upper layer. Several dozens of such organic preparations have already been tested with highly effective results. The structure of the soil is radically improving. It absorbs moisture together with nutrient substances and does not easily give the moisture up. Academician I. Tyurin, well-known soil scientist, be-

lieves that the solution of the problem of supplying agriculture with accessible and cheap structure-forming substances will be an historical event equal in importance to the appearance of mineral fertilizer in the 1840s.

But it is not enough to raise the fertility of the land and increase the crop. It has to be protected from vermin and diseases; it has to be preserved and rationally utilized.

Chemists have succeeded in synthesizing scores of thousands of chemical poisons but only hundreds of them have proved totally fit for agriculture, and even these cannot be used under all conditions.

"Do you know that many flies breed near some DDT-producing factories?" Volfkovich asked us. " 'But how come?' you will ask, 'DDT is an insecticide?!' "

It turned out that flies can adapt themselves to DDT. Therefore new fly-killing agents must be developed. In nature, medicine and agriculture it often occurs that an organism adapts itself to harmful conditions and poisons. In such cases chemists together with biologists must find other poisons. The new agents must be interchangeable and if possible universal.

Flies Adapt Themselves to DDT

"By using chemical agents the people in the 21st century will be able to protect their fields, orchards and forests from vermin and diseases and even postpone the old age of trees," says the academician with a smile. "In the future people will use chemical agents which will combine fertilizer, structure-forming substances, growth stimulators and pesticides. There is still a lot of work chemists must do in association with biologists and agronomists."

It is a pity we could not take a look into the state-farm hot-houses. Soon their glass galleries will run for many kilometres around every electric station and factory, especially in the North.

The abundance of heat and carbon dioxide produced in industrial furnaces will make it possible to organize hot-houses on a large scale, and the hot-houses will operate the year round. Experience has shown that carbon dioxide is a very effective fertilizer.

Not many people know what "agricultural heating" is. Yet agricultural heating has a brilliant future. More and more of our country's thermal electric stations produce simultaneously electric power and heat. An ordinary thermal electric station produces only electric power and frequently throws enormous amounts of heat out of the condenser together with the cooling water. Such an electric station has an efficiency of only 15-20 per cent.

A heat and power plant produces somewhat less electric power but then it supplies the consumers with large amounts of heat in the form of hot water or steam. This heat is used for technical purposes (for the industry) and for everyday needs (heating houses, hot water supply, etc.). But here is the trouble: in winter there are all the heat consumers you want, but in summer their number diminishes considerably. What is to be done with the heat then?

Agriculture can be the consumer of this heat. Experiments have shown that, if ceramic pipes with holes in their walls are laid under the surface layer of the soil, where the roots of plants run, and the plants are watered with hot water underground, the crop will increase substantially. The excess heat inevitably produced at electric stations can be returned to the people in the form of succulent raddish, aromatic tomatoes and luscious potatoes.

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Science will help to increase the crops and, consequently, animal produce to such an extent that synthetic food will hardly be needed in the 21st century. The reserves of agriculture are still enormous. Besides, many types of foodstuffs now used as raw materials in the chemical industry can already be replaced by oil, natural gas, sawdust and many other widespread and cheap natural products. This will release tremendous additional amounts of foodstuffs to be used as food.

Chemists are sparing no efforts in trying to discover the secrets of photosynthesis as a result of which organic substances—carbohydrates and proteins—are formed in plants from carbon dioxide, air and water. The solution of this problem will provide ways and means of utilizing the unlimited resources of solar energy and of producing foodstuffs. Chemists and biologists are studying the essence of the process by which bacteria assimilate atmospheric nitrogen and which operates without the high pressures, high temperatures and catalysts used in industry to bind atmospheric nitrogen in ammonia. The discovery of the mechanism of this process will make it possible to produce nitrogenous fertilizer from the air more rationally and economically. D. Mendeleyev wrote that people would learn to utilize the tremendous mass of sea-water for the production of a lot of nutrient substances and that they would make the first plants for this purpose in the form of a culture of the lower organisms similar to yeast.

We have only taken a peep into the future. What chemistry has so far created is only the foundation for the majestic edifice of future science. There can be no doubt that the "golden age" of plenty is not behind but ahead of us.

At One Table with Poseidon

We came to the Faculty of Biology at Moscow University on Lenin Hills. Amid the numerous laboratories and study-rooms it was not so easy to find the office of Lev Zenkevich, Corresponding Member of the U.S.S.R. Academy of Sciences and head of the Department of Zoology of Invertebrates. Reading the signs on the doors of laboratories and departments even a person who has no particular knowledge of biology will get an inkling of how comprehensive and ramified the science of biology has become in our days. It seems nothing living has escaped the scrutiny of biologists. In the corridor walls, finished in light wood, the architects skilfully concealed many closets. Thousands of most diverse collections and herbariums are kept here as though in an immense museum. And looking at these collections

one begins to wonder if the day will ever come when biologists will finish taking a world "census" of living organisms. And yet, maybe it is already finished and the young people only have to envy the discoverers of plants and animals, who lived in the 19th and the first half of the 20th century?

The academician smiled. Most likely even young students never ask him such questions.

"What would you say," asked the academician, "if geographers suddenly declared they had discovered a new and totally unknown continent? Hard to believe, isn't it? Well then, something of this sort recently happened in zoology when the Soviet scientists sailing on the expeditionary ship *Vityaz* raised from the bottom of the Pacific many species of a new phylum of animals—pogonophores. It turned out that the pogonophores who live in thin tubes up to half-a-metre long are our relatives. They are representatives of a new, heretofore unknown phylum of animals, very close to the phylum chordata to which all the vertebrates also belong. This highly-developed ancient group has persisted in the ocean (mainly at depths of 3-4 and more kilometres, all the way to the greatest ocean depths). To the eight phyla of living organisms known to us the ninth phylum has now been added.

Americas Can Be Discovered Also in Our Time

"An interesting discovery was recently made by the Danes. At a 4-kilometre depth in the Pacific they found a new class of animals belonging to the phylum Mollusca. Outwardly these creatures do not greatly differ from the regular mollusks, only their structure is more primitive, something that warrants the assumption that the mollusks descended from the Annelida.

"What's so interesting about this? you may ask.

"These animals, like many other representatives of the deep water fauna have apparently retained the primitive features of the ancient denizens of the ocean already extinct in the surface waters of the seas. The uniform and constant conditions of existence in the ocean depths seem to inhibit, retard the evolutionary process. The discovery of these animals constitutes a find of one more link in the evolutionary chain which biologists are trying to tie into a single whole to get an idea of how the various groups of animals have developed. By the 21st century there will probably be no more blank spaces on the biological map of the world, and the whole process of evolution will appear more perceptible, more appreciable.

Secrets of Maximum Depths

"A major event in the studies of the seas and oceans came to pass within

the last decade. Strange as it may seem, but we have only just 'discovered' the ocean depths to be able to study them comprehensively.

"Only recently the ocean was sounded to depths not exceeding four or five kilometres. Today scientists are studying the floor of Pacific depressions reaching a maximum depth of 10,990 metres discovered by the *Vityaz*.

"In 1948 Hans Pettersson, a well-known Swedish oceanologist and head of the expedition on the ship *Albatross*, published a book under the title of *Secrets of Sea Depths* in which he voiced an assumption that there was no life at depths exceeding 6,500 metres. He based his assumption on the findings of M. Fontaine, French physiologist, who by placing organisms in a barochamber established that

In the lowest depths of the ocean scientists have found a world of original living creatures.

even bacteria could not exist under a pressure of 650 atmospheres, which obtains at a depth of 6,5 kilometres.

"Ten years ago it was believed that the whole sea floor, deeper than 6.5 kilometres (and this is an area of no less than 7 million square kilometres), was 'dead.' But the explorations of our *Vityaz* during 1949-1952 and of the Danish expedition on the ship *Galatea* in 1951-1952 showed that there were various forms of life at maximum ocean depths and that the ocean had no 'dead' deep zones.

"But I have an idea you are interested in the future rather than the past.

"The ocean..." said the academician as though he saw it before his eyes. "Three-fifths of the earth's surface are not well enough known as yet. Further study of the oceans will lead science to conclusions that are important to all of humanity. We shall have better knowledge of the geological past of the earth and even of the age of our planet after we have studied the ocean depths and especially the floor of the world ocean and the deposits accumulated on it during the past thousands of millions of years. On the ocean floor we shall find the answers to many of the questions facing science.

"How old is the earth? How did the climate change on its surface? Last but not least, how did the level of the ocean itself and the outlines of its shores and the continents change? To answer these questions geologists are

counting and recounting the strata on land. But as a result of derangements in the stratification, the process of weathering and a good deal else, all the sedimentary rocks on the earth's surface were greatly dislocated and mixed up. Here there is a lot that hinders scientists from drawing an accurate picture of the earth's past. The atomic 'clock' (determination of the earth's age by the decay of natural radio-active substances) does not satisfy the biologists. There is another 'clock' which is perhaps more precise, and this is a biological 'clock.'

"Unicellular plants and animals inhabiting the surface waters of oceans die and myriads of their remains sink to the ocean floor in layers. If the Barents Sea were warmer 100 million years ago than it is today, we should find amid the floor deposits, at a corresponding depth, remains of other animals, denizens of a warmer climate. The ocean floor is like an immense museum, a repository where 'archives' of biological phenomena that occurred in the ocean over millions of years lie at an even temperature undisturbed by anybody or anything. It is possible to determine with their aid much more accurately than by any other method, for example, how the climate changed on the earth. It has been established that there were periods of a warmer climate in the area of the Barents Sea both before and after the glaciers.

"The atomic 'uranium clock' indicates that the earth is between 2,000 million and 3,000 million years old, but the 'biological clock' shows something else. Going back into the centuries, to the beginning of the Palaeozoic Era, i.e., 700 million to 800 million years ago, we find the same forms and types of animals that live in our day. In the main they already existed then. Nearly 1,000 million years had elapsed since then. It is unthinkable that life appeared on the earth 1,000 million years before the beginning of the Palaeozoic Era and had enough time to go through all its evolution if the evolutionary course travelled during the subsequent 800 million years is so short. Nor does the history of the development of the earth's living population fit into a period of 4,000 million to 5,000 million years.

Suppose the Atomic Clock Is Wrong?

"Some people may urge, however, that formerly the evolution was perhaps faster. But there are no reasons to think so. The case must rather have been the reverse. At the dawn of life the animal evolution proceeded very slowly but as life developed the rate of its development increased. The earth must have formed at least 10,000 million years ago for life on it to become what it is today. Academician O. Schmidt who has explained the origin of the earth and the other planets in a new way

has also arrived at this figure. Biology and oceanology thus join astronomy, cosmogony and geophysics in their conclusions. Different sciences enrich each other.

"During the coming 20-30 years the strata of ocean deposits will become the subject of detailed study. Today we cannot as yet even say how the salinity of the ocean has changed during its existence. In 1949 the *Vityaz* sailed for deep water explorations in the Black Sea. Incidentally, the Black and Mediterranean seas merged relatively recently, only a few thousand years ago. It stands to reason that in the sea the ground is also salty. But when a sample of the ground lying 4-5 metres under the sea bottom was taken it was suddenly discovered to contain almost fresh water. Geological tubes penetrated into the layers deposited when the Black Sea, very weakly saline, had not been connected with the Mediterranean. By studying the animal remains in the ground and the salinity of the ground solution at different depths of the Bering, Barents and Okhotsk seas it is possible to trace when and how the animal world of the seas changed, when the seas separated from the world ocean, when they merged with it again and how their salinity altered.

Turning the Pages of Eras and Epochs

"By penetrating to a depth of 34 metres below the sea bottom we already go many millions of years back into the past history of the earth. Here is how this is done.

"A percussion pipe with a hydropneumatic device is lowered from a ship. It is a sort of piston pump. If we fill a bicycle pump with air, plug up the outlet and immerse the pump in water, the deeper we immerse it the more will the water pressure compress the air by means of the piston. But oceanologists do not let the air be compressed. They keep the piston 'cocked' and sink the pipe deeper and deeper. The water begins to press on the piston with a force of 500-600 atmospheres. A thin tube, like a syringe needle, is attached to the piston. The moment the 'trigger' is pulled (the valve is opened) the water strikes at the piston, drives the 'syringe' into the ground and a sample is taken. The power for this underwater gun is supplied by the ocean itself.

"New ground tubes are now being designed. These tubes will be able to go to a depth of 100 metres below the sea bottom, to layers which are between 10 million and 15 million years old. They will go through the deposits of the glacial age and will enter the tertiary deposits to a depth of some 50 metres. Such tubes are lowered from ships on trusses and their ends go into the ground. As such a tube is raised the truss pulls on the piston which is

inside the tube. In order to fill the forming vacuum the tube will slowly sink into the ground under the pressure of the water. This is a new and improved method of taking samples.

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Racing the Fish

"It won't be long before the oceanologists renew their equipment. We can hardly imagine the enormous opportunities modern engineering offers to researchers. Devices for boring the sea bottom to practically unlimited depths will be developed. Here the deep-sea submarine fleet will have its say. For local examinations of great depths the French are already using small self-propelled submarines with accumulators. But this is only short-time reconnaissance. What is needed is strong atom-powered submarines not only for exploration but also for fast underwater cruising.

"But is this possible?

"For some reason or other we are not surprised when we hear that fish can swim under water at the rate of 60-80 kilometres an hour. It means that it is possible to build submarines of such shapes and with such engines that, despite the great frontal resistance, they may traverse oceans at a depth of, say, 100 metres, i.e., where they shall not be hindered by storms. Hasn't man been able to go up in the air and fly faster than the fastest bird?! Hasn't he been able to go up so high that his aircraft no longer fear either thunderstorm or wind?!

"Of the numerous instruments we now have, the apparatus for underwater ultrasonic detection is being perfected particularly rapidly. Today whales and shoals of fish are searched by means of ultrasound. The denser the medium the faster the transmission of sound. Sound travels slowly through the air, much faster through water and still faster overland or over the floor of the ocean. Modern long-distance sonars locate from land stations ships almost 1,000 kilometres away.

"If you chance to travel along ocean coasts about 20-30 years from now, you will without fail be shown ultrasonic beacons. Actually these will not be beacons but stations transmitting and receiving ultrasonic signals. All that happens in the ocean—any storm, typhoon, movements of icebergs and ships—will be continuously watched and reported by these stations. It should be observed that they already locate them with astonishing accuracy. The ultrasonic stations find the centre of a typhoon raging way out at sea with an accuracy of up to several dozen metres.

An army of powerful machines was cultivating the virgin ocean floor.

"Somewhere under water, far, far from the coast, there is an earthquake. A gigantic tidal wave caused by this earthquake rolls across the ocean, swallowing islands and coming down upon the coast as a surging black-blue wall 10-12 metres high. This is a tsunami, a dreadful catastrophe which takes but a few seconds to destroy littoral towns with scores of thousands of people who do not even suspect their impending doom.

"But the ultrasonic 'tsunami service' will not let the people be overtaken by the catastrophe. A few seconds after the birth of the gigantic wave the instruments will determine its force and direction. If the tsunami proves dangerous, the automatic signal system will turn on sirens and radio stations. Automatic announcers will call on the people living on the coast to take advantage of the few minutes remaining before the catastrophe and either put out to sea as far from the coast as possible, or climb mountains out of the wave's reach, in a word, to leave town. The disastrous results of the catastrophe will be in large measure assuaged.

"You have undoubtedly observed that we have strayed from 'pure' biology. It could not be helped....

"Modern engineering warrants the assumption that the resources of the ocean will be husbanded, even industrially utilized, if you will.

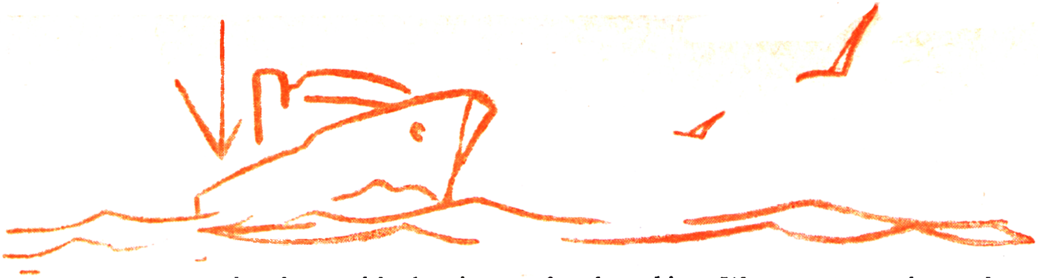
"The seas contain much greater quantities of substances (both organic and inorganic) than does the surface of the land. If we could extract all the gold contained in sea-water it would not cost any more than copper, so great are its reserves.

"Some scientists tried to develop a technology for extracting gold from sea-water. Regrettably, 'sea' gold so far proves many times as expensive as the gold mined on land.

"It may subsequently be possible to find profitable methods of extracting rare and dispersed elements—nickel, cobalt, vanadium and other valuable metals—from sea-water. So far even iodine is not taken directly from sea-water but from seaweeds which concentrate it in themselves. Incidentally, chemists have of late been successfully producing iodine from petroleum.

"What do the scientists so stubbornly want with the ocean depths? Why do they work so hard over dozens of most complicated problems? Wouldn't it really be simpler to produce the same iodine from petroleum and leave the seaweeds alone? What if the resources contained in the oceans are a tempting illusion just as unattainable as gold dissolved in the ocean waves?!

"No! A thousand times no!" said Zenkevich with conviction. "We can-

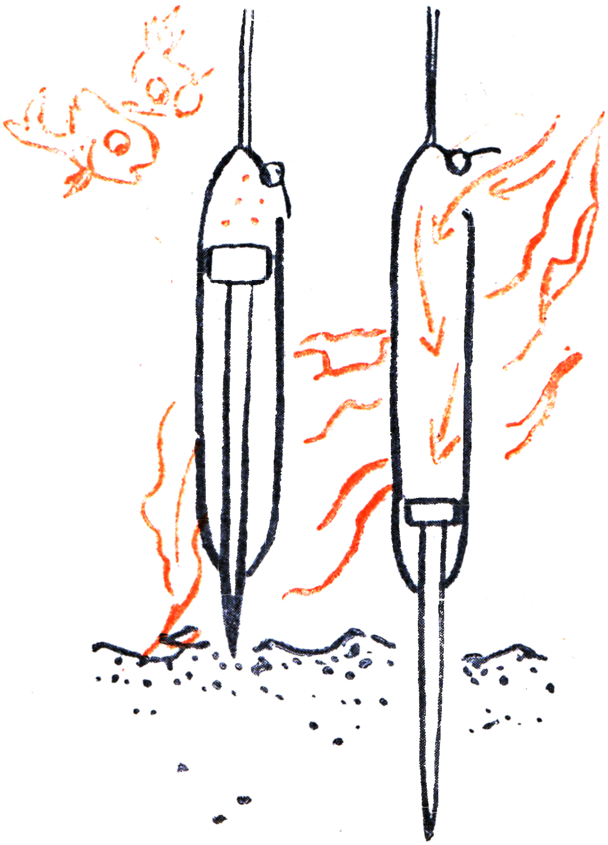


not squander the wealth that is ours for the taking. We must not only catch fish, hunt whales and gather such food invertebrates as lobsters and oysters. We must make use of the whole mass of the marine population in the interests of man. In the 21st century man will manage a vast and well-organized marine economy. And as land agriculture is divided into vegetable-growing, forestry, cattle-breeding, etc., the marine husbandry will also have several branches. Let us take the whales. Suppose a whale was born today. When do you think it will begin to reproduce?"

We tried hard to think of all we know about whales. We recalled that they grow to a few dozen metres in length and 10-15 tons in weight. But we are not biologists and had no idea of the time it takes a whale to grow to adulthood. Perhaps about 10-12 years?

"Oh, don't take it to heart," the scientist encouraged us. "You are not the first to be wrong. Most people know that the elephant, the largest land animal, reaches adulthood, i.e., becomes sexually mature, at the age of 35 to 40. But few people know that the whale, this elephant of the ocean, becomes adult and produces offspring in the second or third year of his life. This unparalleled rate of growth is still a riddle to everybody. And yet biologically this has a simple explanation: the ocean is immeasurably richer than the land in foods, nutrient substances and vitamins.

"On land the vegetation must



The water pressure itself forces the pipe into the loose silt to take samples of the ground

have hard stalks, wooden parts, to resist the wind and reach for the sun. It must have roots, sufficiently strong and ramified to get its nourishment from the ground and to penetrate to the deeper layers for moisture. The plants must protect themselves from withering, great heat and extreme cold. Just think of the energy they must spend on protective adaptation and how little useful, nutrient substances they leave for man!

"The sea is governed by other laws. There the plants do not need any covering, protective elements. They consist almost wholly of the same cells and organic substances as do the leaves of the land plants. Figuratively speaking the marine plants have an efficiency (in content of nutrient substances) of almost 100 per cent, whereas the efficiency of arboreal vegetation does not exceed 5-6 per cent. This is due to the fact that the oceans have ideal living conditions for plants: nourishment from the surrounding medium, favourable, hardly-changing temperature and existence in suspension. It is apparently no mere accident that life on the earth originated in warm ocean lagoons permeated with the life-giving rays of the hot sun.

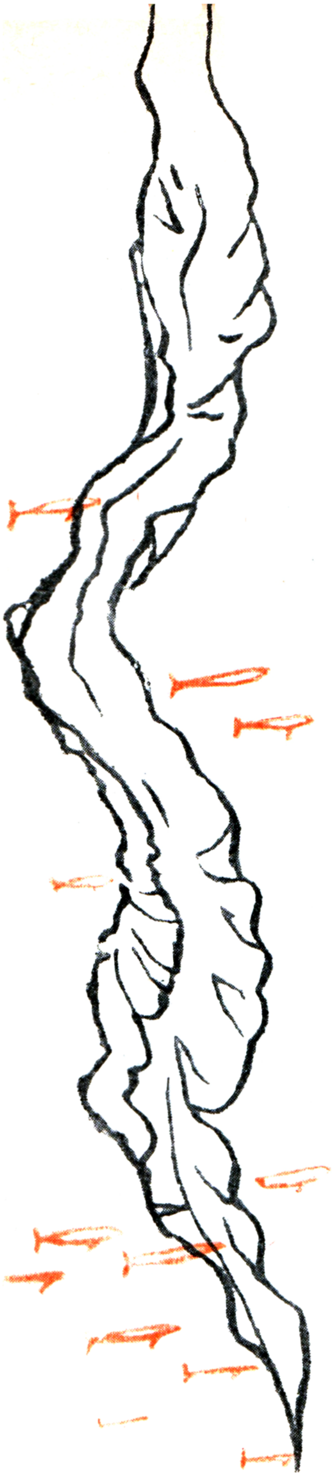
"But it is not only a matter of accessibility and abundance of the nutrient substances of which the marine organisms are 'built.' If we consider the produce of the sea from the point of view of its nutritive value we must also observe something else.

"As a matter of fact, land plants do not, as a rule, have such a high vitamin content as do marine organisms. Especially rich in vitamins and nourishing is the so-called plankton, minutest plant and animal organisms inhabiting the upper layers of the sea in great masses. Interesting enough, by the way, is the fact that, according to its nutritive properties, the plant plankton is very close to the highest grade of meadow hay.

"Willy-nilly you begin to wonder: how come? On land we mow the grass and try to utilize every little bit of organic substance contained in its green mass, whereas in the seas the incalculable wealth of their various organisms remain almost untouched. You may say: but what about the seaweeds, mollusks and crustaceans? Aren't they collected? Yes, but how much of them? Only a negligible part of the mass that inhabits the sea.

Let Us Cultivate the Oceanic Virgin Lands

"Here is what our Czech colleagues write," the scientist opened a journal with a bright cover. "Look: in the nearest future they intend to utilize on an industrial scale *Chlorella*, a green fresh-water weed." He read: "*Chlorella*—valuable source of fodder and raw material for the production of fertilizer, alcohol, petrol and medicaments. A pool for weed-growing yields about 20 times



as much fodder per hectare of water surface as does a hectare of the highest-yielding grasses and requires much lower expense than does the planting of such grasses.

"What makes the marine economy so profitable?

"You go to the forest, cut down all the trees on the allotted plot and plant saplings. Like the elephant (may I be forgiven the comparison!), the trees will grow up and the forest will be restored only in 40 years, whereas in the ocean the organisms constituting the main mass of the earth's vegetation produce 50 generations a year.

"Now you know why whales grow to adulthood not in 40 but in one or two years. They have learned to obtain abundant nourishment from the ocean. But whales are no exception; they are only a vivid example. Thousands of such examples could be cited. Among them we could find curious examples, such as would make you seriously ponder over the laws of nature which creates miracles before our very eyes and seems to say to people: Look and learn. Has it ever occurred to you why the world's largest animals feed on the smallest animals or consume vegetable food? Don't you think that, as far as size and strength are concerned, both the whale and the elephant could easily have become beasts of prey? But they are not beasts of prey. And this is a manifestation of a great law of life, a law of nature. In the tropics inhabited by elephants and in the oceans inhabited by whales nature has created such favourable conditions that the herbivorous animals and the animals feeding on minute organisms are better off than the beasts of prey. Under those conditions it is increasingly harder for the large beasts of

It takes decades to grow a tree, years or even months to grow seaweeds.

The whale grows much faster than even the generally recognized growth record holder—

prey to find food. Nature seems to say to them: If you want to continue developing, growing larger, stronger and more viable (and this is important in the struggle for survival), change to new food. It may be less nourishing than the flesh of your victims but there is a lot of it all around and you will not have to exert yourself hunting, chasing, fighting. All you have to do is adapt yourselves to this food.

"And do you know that some large beasts of prey are accepting these conditions in order to survive.

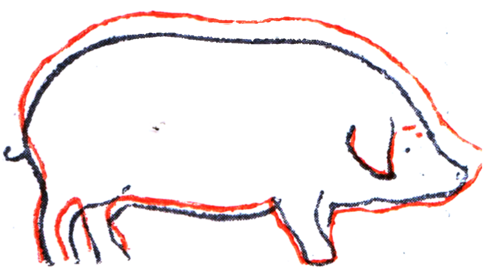
"What is the world's largest fish? Is it the shark? The predatory shark? No, it is not. The largest of the sharks has ceased to be predatory. Like the whale who strains water through whalebone, it also feeds on plankton; it takes in water and filters it. Its ancestors were predatory sharks, but not one of them ever attained to the size of this gigantic 16-metre-long shark which grazes peacefully in the oceanic pastures.

"There you have it, the power of nature. There they are, the means by which man could also work wonders if he should master them.

"A simple device, whalebone is. But man has not yet been able to make so reliable a filter for extracting plankton from seawater. Even ships with special pumps and giant centrifuges which strain the plankton were built. But none of it paid. Another decade or two will pass and we shall be able to draw a mass of plankton from the ocean and transform it into fodder for agricultural animals and perhaps into food for man.

"We can safely say that seaweeds, too, will be used in the 21st century. Nobody has as yet

the domestic pig.



tried to make an exact estimate but there must be thousands of millions of tons of seaweeds in the world. Of these we are hardly utilizing hundreds of thousands of tons today.

"By the year 2010, I am certain of it, we shall hear of the birth of a new science—underwater agronomy, and underwater genetics, if you will. The Barents and Baltic seas, the Sea of Azov and the north-west of the Black Sea with their numerous bays will become the sites of marine state farms. At depths of up to 100 metres where there is a lot of sunshine and warm water agronomists in diving-dress will more around in their fast submarines growing useful plants and animals and breeding new species. Only at great depths where it is dark and where the temperature is only 1 or 2° C and the development of life is retarded will there be no underwater fields or orchards.

The Seas Have to Be Fertilized

"In spring the phosphorus and nitrogen suddenly disappear from the seawater. They are absorbed by the rapidly growing seaweeds. The plants are experiencing a phosphorus and nitrogen hunger; the sea does not have so much of these substances. Give the seaweeds fertilizer and they will produce for you a crop that will be the larger the more phosphoric and nitrogenous compounds you dissolve in the water. But this also needs an agronomist, or a 'marinomist,' to be exact, a marine plant expert. We do not introduce fertilizer in winter on land either. We must know precisely what fertilizer the marine fields need and when they need them. 'Mariculture' is no simple matter.

"Marine animal husbandry will also develop. It will hardly be possible to breed whales in nurseries but it is worth trying to transform all the world's oceans into a nursery. Whales need space. They live in the Antarctic only in summer and migrate to the subtropics, thousands of kilometres away, for the winter. Nobody knows precisely where they reproduce nor what route they travel. One thing is still uncertain, namely, whether it is the same whales who live in the northern and southern hemispheres or different herds.

"Whaling must be put in order. The first whale protection measures were recently introduced. If these measures are carried out the whale herds will not only be preserved but even increased."

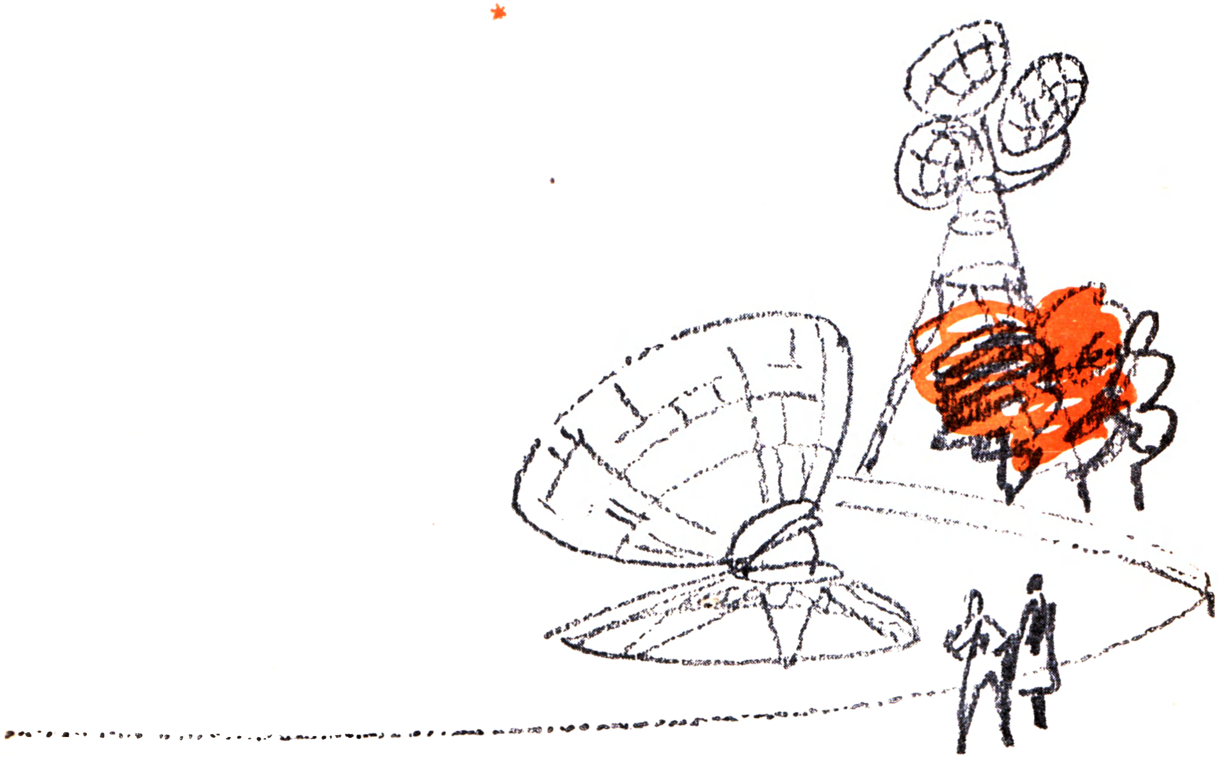
For a moment the professor stopped. Fascinated by the subject he could have told many more interesting things. But. . . .

"Excuse me, but my time is up. I have to examine a student."

The professor walked over to the glass door, opened it and bid the student patiently waiting in the corridor:

"Won't you, please, come in, young man?"

THE AGE OF RADIO



The Second Fifty Years in the Life of Radio

The Revolution in Intellectual Work Has Begun

Man Will Kindle an Artificial Sun

The Second Window onto the Universe

The wonderful properties of magnetic iron ore, which attracted metal articles, or of amber, to which, when rubbed against a piece of cloth, bits of fluff jumped and adhered, as if glued with some invisible glue, evoked in the ancient peoples superstitious surprise and almost awe.

Thousands of years had to elapse before people could divine the relations between the electric and magnetic fields. It required the genius of Faraday. Heinrich Hertz was the first to peer into the realm of electromagnetic oscillations. Alexander Popov found this new realm to be very useful for man and proved it.

To be sure, electromagnetic oscillations, the science about which was born but a little over 70 years ago, is a realm of magic opportunities.

Isn't speaking over thousands of kilometres, from one continent to another, a magic opportunity?

Isn't it a magic opportunity to see clearly through the pitch dark of a moonless and starless night, when the unaided eye fails to discern even the fingers of one's own outstretched hand?

Isn't transmitting a moving image with all its clear outlines and wealth of colours over scores and even a good hundred kilometres a magic opportunity?

And isn't it really a magic opportunity to suspend in the air, heat to white heat and even melt a piece of refractory metal without in any way touching it?

This list of but very recently unthinkable miracles, which, owing to the discovery of electromagnetic oscillations, are for many people commonplace reality today, could be continued *ad infinitum.* If we were to date each miracle in our long list to indicate when it was first performed we should find that the closer to our time, the more new and wonderful miracles have been discovered in the world of electromagnetic oscillations. In the beginning new miracles were being discovered about once every ten years, then they began to be discovered annually, and now man discovers several of them every year—several new uses for electromagnetic oscillations in the most diverse branches of science and engineering.

Many ideas of using high-frequency electromagnetic oscillations are still waiting to be carried into life. These ideas are in the fields where man has never set foot before but which are already clearly visible from the peaks reached by man.

Here we find wonderful road-building machines slowly creeping in a cloud of grey smoke through virgin land and leaving a smooth, mirror-like, newly-built highway behind them.

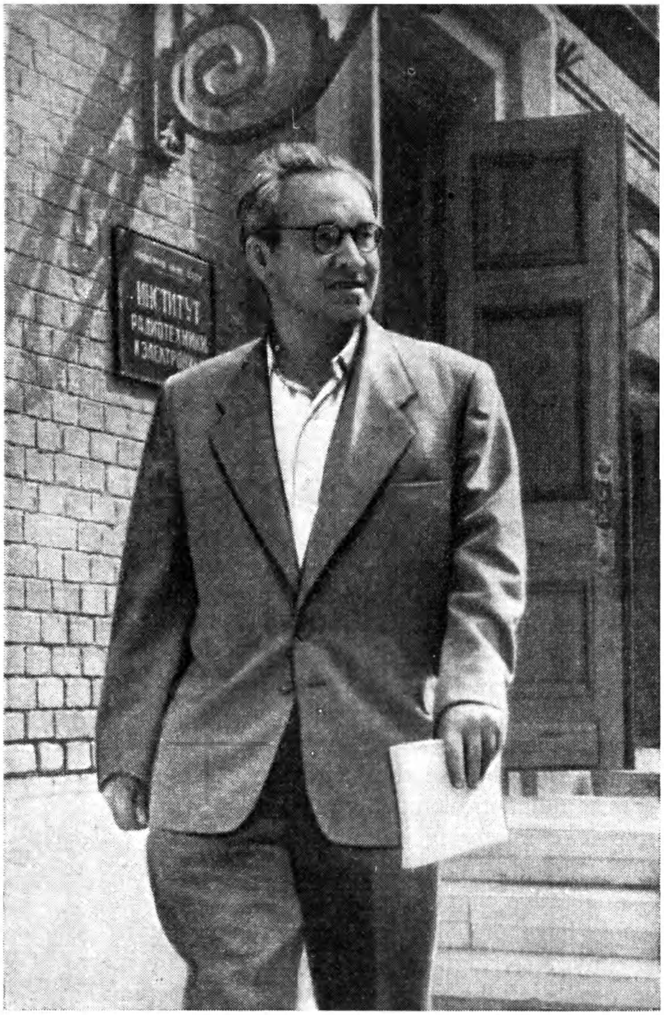
Here we see different vehicles which have neither tanks with fuel nor wires to feed them power—nothing save parabolic antennae to receive radiant energy.

Here we have unprecedented aircraft traversing thousands of kilometres without a single drop of fuel on board.

Here we observe an artificial sun shining day and night over the cities of the world.

Here, too, we note remarkable machines reconnoitring remote planets and reporting the results of their observations to man on earth.

Many scientists have told us about the unexplored fields of electromagnetic oscillations, the realm of high-frequency currents. In this chapter we give the reader the stories which more than any others have to do with this branch of science.



The Second Fifty Years in the Life of Radio

Academician Vladimir Kotelnikov has his study in the old building of Moscow University in Mokhovaya Street. In this place, at one time frequented by Pushkin and Lermontov, Lebedev and Zhukovsky, Timiryazev and Stoletov, the Soviet scientist, one of the greatest specialists in radio engineering, told us about the future of this science.

"The radio was born relatively recently. A little more than six decades has elapsed since that day in May when the great scientist A. Popov made his report 'On the Relation of Metal Powders to Electric Oscillations' and demonstrated his storm-indicator at the Russian Physical and Chemical

Society. Under the above modest scientific title the author told the world about his great discovery all the results of which we cannot conceive even today.

"It is no easy matter to see 50 years into the future of radio. It is nearly the same as trying to tell about modern television and radio location at the time of Popov's storm-indicators and the first experiments in wireless communication. The teller of such stories would be dubbed a groundless dreamer. And yet I am sure that the second fifty years in the existence of radio will be marked by no less important fundamental discoveries and that the radio will find no less significant new forms of application than was the case during the first fifty years. Of course, we cannot even divine all of them today. We shall therefore talk only about those new things that have at least already given the first sprouts.

"Mastery of increasingly shorter wave lengths has been the general tendency in the development of radio engineering during the recent decades. The wave length newly mastered during each five-year period—in average figures, since it is an uneven process—was cut to about one-fifth the preceding wave length. There can be no doubt that this process of mastering ultra-short waves will continue for some time to come. Whereas today we confidently operate with centimetre wave lengths, we shall undoubtedly soon begin to use waves only fractions of a millimetre long.

"At first sight this process of mastering increasingly shorter wave lengths is of a quantitative nature. But the quantitative changes may lead to a number of revolutionary qualitative changes in radio engineering.

Pocket-Size TV Set

"Most people have probably read scientific-adventure stories describing tiny receiving and transmitting sets by means of which the people of the future will be able to communicate with each other at any time at all. Millions of radio broadcasting stations operating simultaneously! How can they be accommodated within the range of wave lengths already mastered but also filled to the limit? Today we can effect no more than a few dozen simultaneous telecasts at any one point. Only the mastery of millimetre and shorter wave lengths will make it possible to distribute in the ether a practically unlimited number of channels not only for radiotelephonic communication but also for telecasting."

*

While the scientist spoke, pages from science fiction stories came to life and rose before us. Domestic radio appliances of the 21st century....

. . . Early Sunday morning. You remember that you failed to make up with your friend about the contemplated trip out of town. You reach out and pick up from the night table a small object, the size of a cigarette case. It is an individual TV transmitter-receiver, the kind every person on our planet has. You turn on your friend's signal call and press the call button. Flickering ripples appear on the greenish screen of your receiver indicating that the receiver you are calling is busy—your friend is talking to somebody else. But the sets are so constructed that your friend is notified about your call. Now it is up to him either to take your call immediately or let you wait till he is through.

It turns out his is no secret talk. The screen of your receiver grows lighter and shows the familiar face drawn so clearly by the crayon of the electronic ray that, despite the small size, you can count the eye-lashes and freckles on his face. Sound comes on at the same time. It happens that your friend is talking about the same out-of-town trip.

The sentence is finished and the face of the other interlocutor appears on the screen. You break into the conversation but the screen does not fade out, you see both faces, watch their expressions and probably wonder how the people of the 20th century spoke to each other by telephone—not even by radio—without seeing each other. Yet it is so important to see the person you are talking to.

The friends begin to argue about the itinerary. They have to consult the map. Clear as the image on the screen may be, the map of Moscow Region the size of a postcard is certainly not the best aid in working out an automobile trip in detail. You turn on your room TV set with a screen taking up a whole wall and see the map hanging in the tent of your friend who is spending his vacation some hundred kilometres away from Moscow. You pick your itinerary as if the three of you were bending over one table.

Wall or TV Tube?

. . . It is a wonderful trip. It is a pity though you cannot attend the football game to be played at the Lenin Central Stadium in the afternoon. Then why not see it on the individual TV sets? And there you are, sitting on a steep shore of one of the Volga seas and breathing the fragrance of the spring forest you watch the hard-fought game.

"Of course, there will be TV sets small enough to fit the vest pocket and very large ones with screens of several square metres," said the academician. "A large screen will not necessarily mean a large TV set. The set itself will be like a picture—flat. The screen will be very thin. Semi-conductors will be

one of the means that will make it possible to reduce the size of TV sets and all radio devices in general.

"The use of very short radio waves may cause an even more amazing revolution in chemistry.

"Let us picture to ourselves some molecule roughly and simplified as a structure with various branches and various individual parts. The own osciliations of these parts may coincide with some particular radio wave frequency, may be resonant. By irradiating a substance with such radio waves it is possible to 'break off,' destroy parts of the molecule, tear them asunder and change their structure, i.e., alter the chemical composition of the substance. By the action of radio waves it will be possible to accelerate reactions to a much greater extent than by most powerful catalysts; it will be possible to carry out such processes as now operate with enormous difficulty or are considered practically unfeasible.

Radiochemistry

"Of course, it is still only an idea. It will take many years of work to find concrete methods of utilizing this idea, to get an insight into the interaction between the various substances and different radio waves, etc. But I am certain that the birthday of the new science—radio-wave chemistry—is not far off and that it will be followed by a period of its mighty creative maturity.

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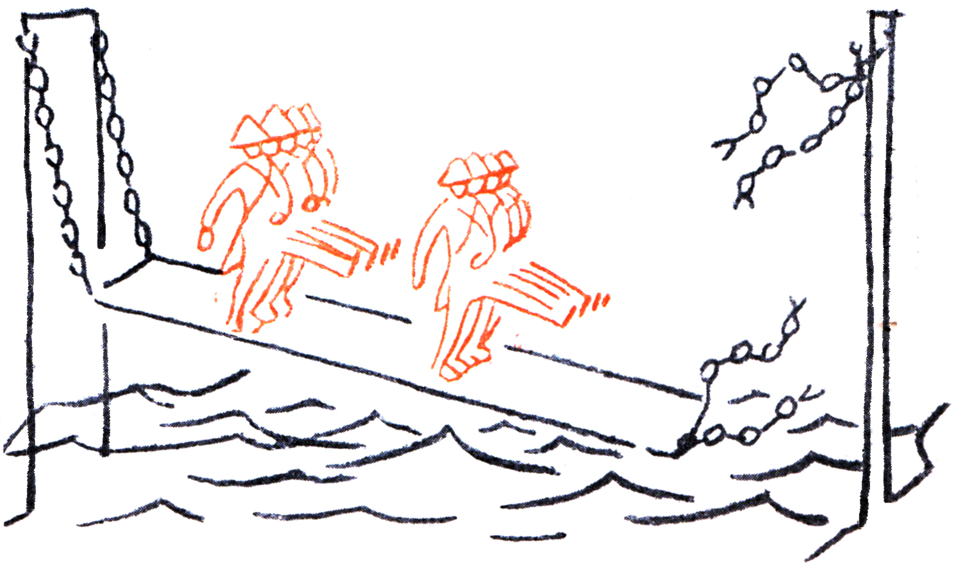
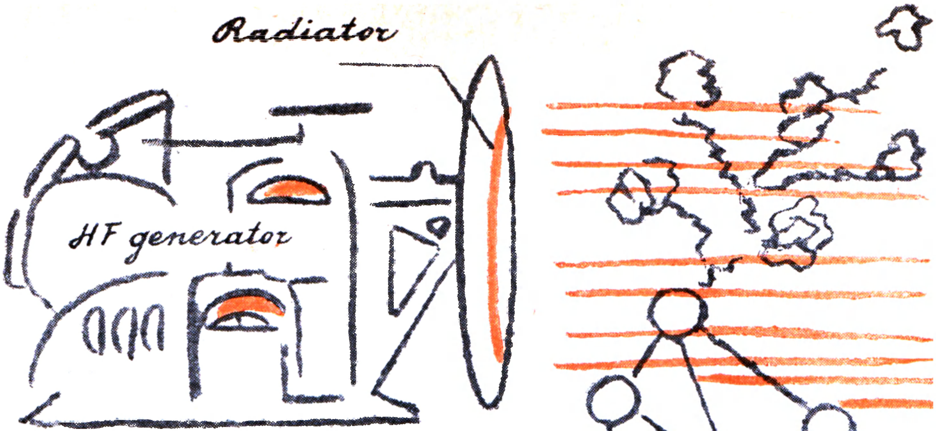
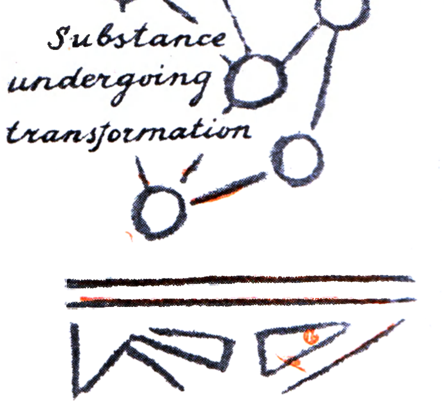
"I want to focus your attention on one more very interesting and rapidly developing branch of our engineering whose progress, however, would be







It appears resonance can destroy not only bridges but also molecules and thus create new substances.

impossible without the development of radioelectronics. I am referring to the so-called electronic computers and other 'thinking' machines. I am sure that in the 21st century you might see, for example, the following machine.

"... It stands in the left corner of the desk taking up no more space than an ordinary typewriter of the middle of the 20th century and, although white sheets of paper are sticking out of it, it does not have the numerous keys with letters without which a typewriter is unthinkable. There are only about 6 or 7 tiny buttons on its front.

"To turn it on, you must press a button. Let us press at random two or three more buttons because, as long as they are there, there must be a reason for them. Now let us talk about anything you like, say, about engineering of the 22nd century. We shall come back to this silent apparatus a bit later.

"We talk for about ten minutes, our conversation abounding in all sorts of remarks and rejoinders and frequently in unfinished questions since we understand even each other's hints. At the end of our conversation we press one more button on the typewriter of the 21st century and it throws out several sheets of thin paper covered with clear print.

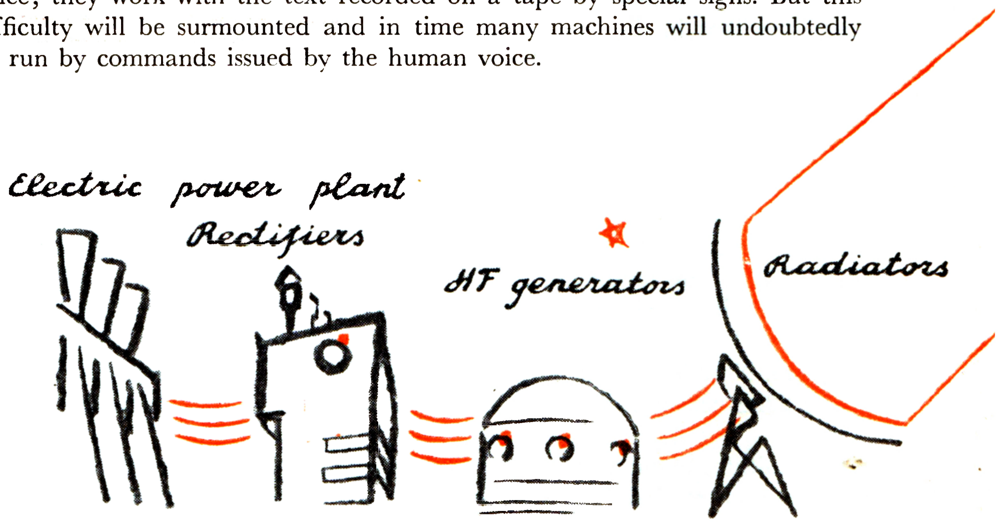
"Some of them contain the exact text of the conversation. Incidentally, not very exact, since the typewriter has corrected, no worse than a literary editor, the wrongly built sentences and supplemented them striving for precision of expression. Not all the sentences have come out equally nice; some of them are a bit awkward and crude but all are grammatically correct, which could not be said of the recorded conversation.

"Other sheets contain a translation of the same conversation into French and English. It was we who asked that our conversation be translated into these languages by pressing the very first buttons that came to our hands.

"Such an automatic stenographer and translator is no fantasy even from the point of view of present-day engineering.

"Machines are already making translations from one language into another. To be sure, they are still extraordinarily cumbrous and do not have a very large vocabulary, for which reason they 'specialize' mainly in scientific texts. It is not difficult, however, to develop a machine for editing the style of the text, since sentence construction is governed by certain rules in any language and the machine is capable of observing any rules we may dictate to it.

"Today these machines are as yet unable directly to perceive the human voice; they work with the text recorded on a tape by special signs. But this difficulty will be surmounted and in time many machines will undoubtedly be run by commands issued by the human voice.



And a plane will rise to the ionosphere along the power ray as though along a road that leads to the sky.

"Now let us briefly discuss power transmission without wires. Of course, I do not mean the negligible quantities of power which every radio set receives through its antenna, but of transmission of power sufficing, for example, to set an aircraft propeller in motion. Undoubtedly, this problem will also be solved. An aircraft up in the air will receive the power for its flight from the earth in the form of a beam of directed high-frequency oscillations, like the beam thrown by a projector.

Power Beam Instead of Wire

"We can picture to ourselves a Moscow-Sochi line equipped with such power stations. There will be only four or five of them all along the route. An aircraft with not a single drop of fuel on board, but for that reason carrying twice as much cargo and twice the number of passengers and flying much faster than our present-day planes, will take off along the power beam in Moscow and then will be intercepted successively by the power beams of the Tula, Orel, Kharkov, etc., stations. It will be a sort of aerial trolley-bus without wires.

"Can a power beam become a weapon? Hardly. It will be very easy to reflect it by means of a well-polished surface of the aircraft body, as a mirror

reflects a ray of the sun. On the other hand, it will probably be able to clear the way from meteors for a spaceship.

"To be sure, it will not be easy to manoeuvre a ship flying in interplanetary space at a speed of dozens of kilometres per second. Yet the collision of such a ship with a meteor, even a small one but also possessing enormous speed, will be equivalent to the impact of an armour-piercing shell on a balloon.

"I picture to myself astronauts fighting meteorites in the following manner:

"The spaceship will continuously feel the space about itself with a series of pulses from its radar set. The moment it detects a meteoric body at a dangerous distance, electronic devices will be turned on to determine whether or not there is any danger of collision. If a collision appears unavoidable, a mighty power beam will be thrown in the direction of the meteoric body. There will hardly be any meteoric bodies in space with protective reflecting surfaces. Under the influence of the power beam the substance of the meteorite will be heated, will crumble and evaporate from the heat. The spaceship will encounter but a light cloud of vapour instead of a spaceshell. The whole thing will take but a fraction of a second."

The Revolution in Intellectual Work Has Begun

One hundred and fifty years ago there were, naturally, no electronic computers nor electronics, the science which developed them. There was only a dream of creating a mechanism capable of doing the work usually done by the human brain. Sometimes this dream produced somewhat unexpected results.

The story goes that one day Napoleon Bonaparte sat down to play chess with an amazing partner—a mechanical chess player. The inventor of this wonderful mechanism demonstrated its construction—an intricate combination of wheels, gears and levers housed in a metal casing.

They say that despite all the efforts of the great general who had won so many brilliant victories on the battle-fields he was utterly defeated on the chess-board.

Incidentally, soon the secret of the mechanical chess player was out. A man of very small stature was hidden in between the parts of the mechanism. He was not a bad chess player but, when a fire broke out in the room where the next game was being played, he had to abandon his shelter.

A Science Without a Past

In our days chess playing machines really do exist. Rumours have it that one of them played grand master Reshevsky to a draw. These are electronic computers—machines that are supposed to mechanize intellectual work, as tractors and combines, excavators and blooming mills mechanize man's physical work.

It is to talk about the future of these wonderful machines that we went to see Academician Sergei Lebedev, one of the most prominent specialists in this branch of science and head of the Institute of Precision Mechanics and Computing Engineering of the U.S.S.R. Academy of Sciences.

"It is hardly possible to speak about the future of our branch of engineering," said the academician. "Scientists barely manage to take advantage of the many interesting opportunities which the electronic computers offer to science already today. There are so many examples of it that I really do not know which the readers might consider the most interesting.

"The first of these machines was developed in 1945. In the course of 15 years mathematicians have learned to solve with the aid of these machines problems of unimaginable complexity. Suppose I give you a plain example.

"Every schoolchild knows that it takes two or three minutes to solve an equation with two unknowns. But to solve a system of 200 equations would take a million times as long. This means that a person who decided to do it would have to spend 12 years, day in and day out, working with pencil and paper on this problem. A machine solves such a system in less than an hour. In just one hour it compiles a table of logarithms on which mathematicians formerly spent dozens of years. You can judge for yourselves.

"But even these speeds no longer satisfy the mathematicians and physicists engaged, for example, in subatomic research. The machines already solve the most complicated equations in partial derivatives. Science is increasingly facing problems which cannot be solved without accelerating the speed of the machines.

"At first," said the scientist, "the machines perfomed barely 1,000 operations a second. Today they perform at least 10,000 operations and in

the nearest future they will perform hundreds of thousands and even millions of operations a second.

"Let us take construction, for example. It was in no way possible to determine precisely the shape and steepness to be imparted to canal banks so that they may not crumble. Calculations were made, but no sooner did the builders drive a few hundred metres than the composition of the ground somewhat changed and the calculations were of no use any more. Thus because of a trifle, a minor mathematical inexactitude, we lost millions of rubles on earth work. The computing machines save all this money for the country.

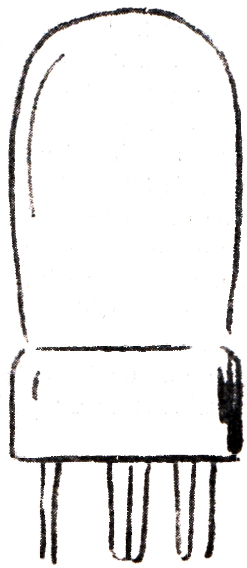
"Meteorologists have begun to forecast the weather with greater accuracy now that the meteorological data are worked up by machines. With the aid of these machines it is now possible in one hour to forecast next day's weather for all of the Soviet Union.

"The mathematicians' electronic assistants make it possible to try out rapidly numerous variants of a problem and choose the best one. It is thus possible to determine the most suitable shape of an aircraft wing, the nozzle of a jet engine, the turbine blades, etc.

"Computing centres have been organized and computing machines are already working in our country. The Seven-Year Plan envisages extensive introduction of electronic machines. Special attention is to be devoted to production. Electronic machines will be able to run production units, production lines and perhaps even whole plants. Machines will help man to operate most complicated technological processes which require constant attention, consideration of many different factors and, at times, instant decision.

"Say, chemists have to synthesize a substance with certain properties. Of what components should the new substance be 'built'? The machine will help to answer this question. It will analyse the properties of hundreds of substances, will compare these properties with the ones required and will suggest which two or three substances may form its basis.

"Even the most capable and industrious apprentice will be unable to imitate precisely the movements of



A transistor is 10 times as durable, 100 times as small and 10,000 times as economical as a radio valve.

a skilled worker who during the dozens of years of his work has learned all the finest points of metal working. Does this mean that his skill will die with him? No, it does not. We can record, copy every movement of the skilled worker and feed the record-programme obtained into an electronic device which will run a machine-tool automatically. Such automatic machine-tools already exist.

"Any part, even one with the most complicated shape, can be described by a series of mathematical formulas. Fed into a control device these formulas will ensure precise machining.

"It is hard to say what would have happened to statistics without the help of computing machines. Automation of the technical aspect of statistics frees numerous employees from wearisome computations.

"Say, the radio engineering industry plans to put out 10 million TV and radio sets, each set having thousands of different parts. They are manufactured by hundreds of specialized enterprises. The machine will quickly draw up the production plan for each of these enterprises."

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Academician Lebedev spoke sparingly but forcibly and each idea called up fascinating pictures in the mind.

"Somewhere in the Transcarpathia, in the very centre of a tidy Ukrainian village one of the houses bears the sign of 'Bibliotelecasts.' Boys and girls, apparently last year secondary school pupils and students living in this village enter the house. Each of them comes promptly at the appointed time. One must not be late because bluish TV screens have already been turned on in the booths that look like those used for long-distance telephone calls. The whole group of pupils, admirers of the great Taras Shevchenko, attentively read some of the rarest documents from the biography of the author of 'Kobzar' being demonstrated on the screen. In the neighbouring booth the screen is filled with columns of formulas and an invisible lecturer is helping some future technician to master the elements of higher mathematics. Only this morning the teacher advised this student to review one of the branches of mathematics with the aid of the bibliotelecast and even sent a note with the student, which read:

" 'Dear Comrade Bibliotechnician, please help our student to call up a lecture on mathematics from Lvov today. Perhaps it would do well to record the telecast on a tape in order to have it at hand.'

"It seems miracles will never cease. Who is this bibliotechnician? And how can you call a lecture from Lvov?

"It appears that the bibliotelecast is a telecast of any literary, historical and scientific information in response to individual inquiries.

"Your Occupation?" "Bibliotechnician."

"To listen to the radio, it is not at all necessary to have your own radio station. It is enough to have an ordinary loudspeaker. Hundreds, even thousands of loudspeakers are connected with wires to a radio realy centre which conducts the broadcast. The bibliotelecasting system works in the manner of such a radio relay centre.

"There are not very many books in the village library compared with the Lvov Regional Library and the libraries in Kiev or Moscow. The large libraries have so many books on so many different subjects that hundreds of consulting bibliographers have to be engaged in reference work. But even they cannot remember everything and must keep digging, days on end, in different catalogues looking through thousands of cards in order to get the one you need.

"Man will not have to burden his memory with a mass of unnecessary technical information. He will be helped by the 'memory' of the so-called electronic information machines. Upon request the machine will immediately find the necessary cell and will set the recording tape in motion, reproducing not only the sound but also the image.

"The archives—film catalogues—of the bibliocentre contain extensive information, and the electronic machines 'remember' every piece out of the millions of recording tapes and every microfilm. It is these machines that transmitted to the Transcarpathian village the lecture on mathematics and told the pupils the story of Taras Shevchenko. Now you should understand the part played by the village bibliotechnician. He forwards his readers', the TV spectators to be exact, applications to the regional bibliocentre, and looks after the work of the screens. A bibliotechnician is a librarian of the new century.

But Foreign Languages Must Be Studied Just the Same

"... An international conference. Keeping only a word or two behind the speaker the translating machine, about the size of a desk, instantly carries the meaning of the speech to every listener whatever his language.

"We can dream of such a translator with good reason even now. The question is only how fast he can work. We can already see a way of expediting the work of the machine. We are now using mainly universal machines which can be readjusted and whose methods of computation can be altered.

But universal machines are rather cumbrous and complicated. There are simpler specialized devices designed for one certain class of problems, but these devices can work much faster. This resembles the specialization that is taking place at industrial enterprises.

"The computing machines will facilitate and expedite man's work and will take the burden of monotonous arithmetical calculations off his mind.

Man Is Indispensable

"It is a terrible thing to say, but the labour productivity of industrial workers has gone up 1,400 per cent during the last one hundred years, whereas that of office employees increased only 40 per cent. Monstrous disparity! But there will be an end to this in the nearest future. The revolution in intellectual work has begun.

"Machines will help man and in some things will even surpass him, but they will never be able to replace man. The human mind will continue to improve its mechanical child. Only man can suggest the most economic way of solving a problem and propose a new and more perfect programme. The speed and reliability of machines is increasing; they are becoming simpler in construction and smaller in size. Whereas the first electronic machine had 18,000 valves, today their number has decreased to 4,000, and before long they will disappear altogether because they will all be replaced by semi-conductors.

"The introduction of such machines, the reorganization of man's intellectual work," said the academician in conclusion, "can be compared in its results only with the replacement of manual labour by machine labour which took place several centuries ago. Machines have revolutionized physical labour. We are now taking part in the revolution of intellectual work."

Man Will Kindle an Artificial Sun

"We should like to dream of the 21st century together with you," we said to Professor Georgy Babat as we crossed the threshold of his small laboratory. The professor is well known for his work in the field of industrial application of high-frequency currents (HFC as they are called for short).

The laboratory was encumbered with radio apparatus, strange panels, and steel and copper wires rolled up like coils of rope on board a ship.

"Careful now, do not touch the instruments, they are turned on," the professor warned us.

Looking round apprehensively lest we sit down on some electric chair we took out our notebooks.

It would be hard to say what constitutes the most important part of Professor Babat's life—his scientific or literary work. He is at once the author of many most interesting inventions and entertaining popular science books and articles. It is he who proposed high-frequency steel hardening, road building by caking the ground with high-frequency current, the high-frequency drill and high-frequency transport, supplying planes with power by means of a power beam and a singing electric sun. As a source of most original scientific ideas he is inexhaustible. Recently he showed us the proofs of his big novel *Magnetron* coming off the press soon.

Poet with the Soul of a Physicist

But today we came to see Babat the scientist rather than the writer.

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"You said 'dream'," the professor began. "But if the dream does not rest on a solid, rational basis, it smacks of hare-brained plans. The thoughts of a scientist or inventor may wander into the future, but this is the more reason why the scientist or inventor must have both their feet firmly planted on the ground. There have been cases in the history of engineering when even brilliant inventions lived but a very short time. For example, Yablochkov's candle flashed brightly and immediately faded, whereas A. Lodygin's incandescent lamp is still burning today. Many creative ideas, many seeds of tomorrow are ripening in science and engineering today, but not all of them will sprout. 'Many are called but few are chosen,' says the proverb.

"One naturally wishes to pick out such seeds, such ideas as will really blossom out tomorrow. And this is precisely the investigator's and inventor's task. Yet it is not easy to find them and determine just the things that may develop during the coming decades. This is probably why the science fiction stories sometimes appear so pitiful. The writers apparently pick the wrong seeds.

Radio-Receiver Instead of the Motor

"You say you are interested in high-frequency transport and its future. Its principle is simple. If we pass high-frequency alternating current, i.e., current that changes its direction several hundred times as fast as in the usual electric circuit, through an overhead wire or an underground cable, a rapidly alternating electromagnetic field, from which power for the so-called HF transport can be drawn, will appear around the wire. Electric signals are received in the form of radio waves by the antennae of ordinary radio sets but their power is fit only for communication and not for further power use. But the HF-

We visited one of the stations that nightly kindled an artificial sun over the city.

mobiles will be equipped with essentially the same radio set having a receiving antenna which encircles the machine. The electric current will arise in this antenna and after a series of transformations will drive the electric motor.

"Radio engineering has now developed to such an extent that it has made possible the flight of aircraft and rockets guided by a remote control device, which is, as it were, the 'brain' of the machine. Tests of HF-mobiles developed in the U.S.S.R. in 1943, at the height of the hardest of all wars, showed that HF power was not only the 'brain' but also the physical power of the vehicle.

"To equip the vehicles with electric motors which receive their power without wires, it is necessary, in the first place, to produce an abundance of electric power, and this is why the heyday of HF transport will most likely come in about 15-20 years.

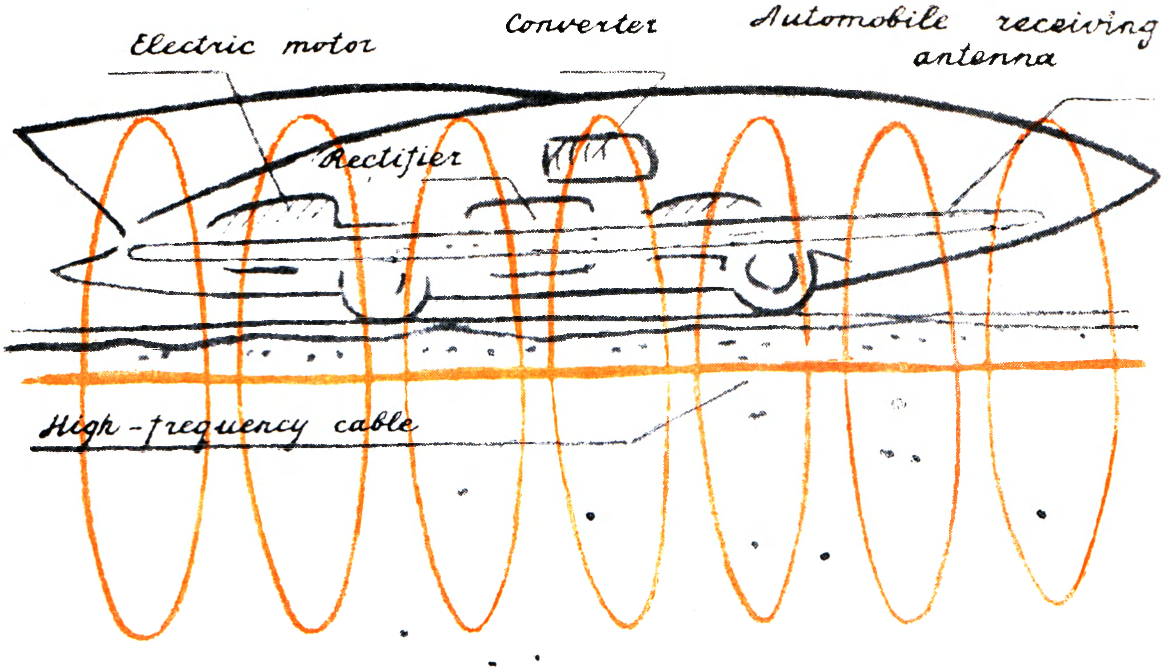
"To equip the streets and roads for HF traffic, the asphalt and concrete will have to be broken up, cables laid at a depth of less than 50 cm. under their surface and electric substations built along the roads.

"This is the hardest and costliest part of the work. It does not as yet pay to lay such cables on the long-distance highways (Moscow-Simferopol, Moscow-Kuibyshev, etc.).

"HFC has a competitor in the sprouts of another 'seed' which promises an abundant harvest. You know that super-long-distance atom-powered submarines are already plying the oceans, that an atom-powered ice-breaker has been built and that atomic engines are being designed for aircraft which will be able to circle the globe several times without landing for refuelling.

"But you cannot install a cumbrous atomic engine on a light vehicle. This is why it will be expedient to introduce HF transport in the towns and suburbs to take the place of the vehicles driven by atomic or internal-combustion piston engines, which by the end of the century will no longer serve their purpose. HF-mobiles can very well be used for transportation inside industrial enterprises.

"Semi-conductors, a new ally of HF transport, have grown up and gained strength in recent years. Have you ever heard the expression 'slumbering circuits'? These are underground wires which usually consume no power. As soon as a HF-mobile appears on the highway a 'slumbering circuit' awakens, supplies the vehicle with power and dozes off again, saving electric power. Such a 'slumbering circuit' can serve for dozens of years on end, at the same time using much less power than we are now spending on lighting a route of



It's a good thing not to have to worry about the fuel for your car.

the same length. These merits will be imparted to the new power supply system by semi-conductor elements.

"There were times when a concrete road was considered an impermissible luxury. Today it is the usual thing. In the 21st century concrete highways without built-in HF cables will appear incongruous. Power lines will be built in the highways during their construction just as the water-piping, sewerage system and electric wiring are brought to a house when its foundation is being laid.

Slumbering Circuits

"When building a highway of concrete slabs, we shall put semi-conductor units, consisting of two or three elements and measuring several cubic millimetres, into the roadway 50, 100 or perhaps even 500 metres apart. This will be precisely the simplest automatic relay which will 'wake' the section of the circuit whenever necessary. If we picture to ourselves the high-frequency line as an electrical 'nervous system' each of these relays will be a sort of nerve cell. These relays are still being made by hand, and this is why a semi-conductor relay is yet as costly as an electronic valve. Of the two semi-conductor materials—germanium and silicon—occurring in nature, silicon is the most widespread. It is a constituent

and the basis of ordinary sand. The trouble is, however, that semi-conductor devices require silicon of special purity. To purify it from its admixtures is as yet a labour- and time-consuming affair and silicon is therefore a million times as expensive as the sand from which it is extracted. The artificial nerve cells in the electronic brain are also built of pure silicon. Unlike the human brain consisting mainly of carbon, the electrical 'brain' and the electrical 'nervous system' are made of silicon.

"In the light of the latest achievements of nuclear engineering it sometimes appears that electrical engineering has already exhausted its possibilities for development. But this is not the case at all. Electricity has been and will remain the most adaptable and convenient form of power, and we have not as yet taken full advantage of the opportunities it offers. High-frequency currents are now offering particularly interesting and extensive prospects.

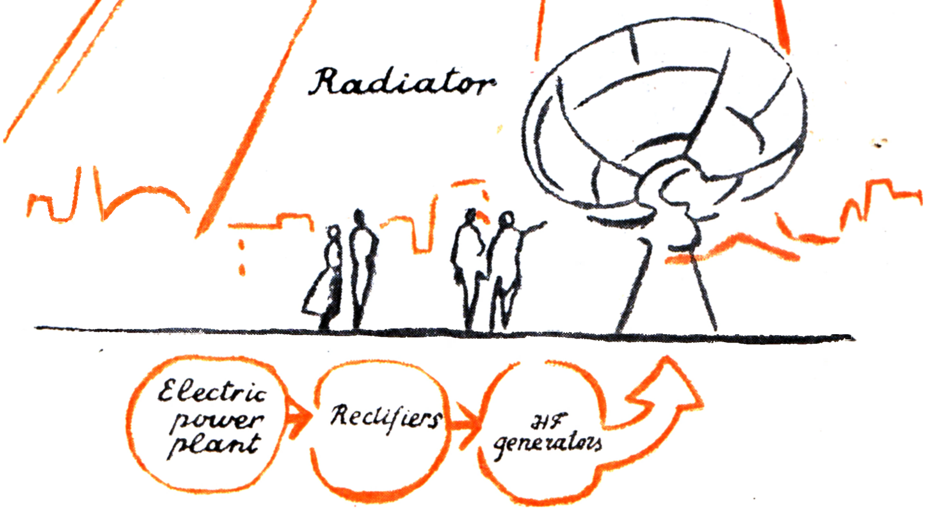
"High-frequency current began to be used essentially only after the invention of radio apparatus operating on electronic valves. Radio communication required electricity. The radio broadcasting stations consumed less than one per cent of the total electric power produced. The streamlet of high-frequency power began to murmur and became visible only after the First World War. And at the end of the 1930s, when electrothermics—smelting and hardening metals by high-frequency currents—developed, plants consuming up to 100 kw. of electric power made their appearance. Their number kept increasing. It turned out to be profitable to smelt and harden by means of high-frequency current the grades of steel which require high chemical purity. Today there are HF plants consuming thousands rather than hundreds of kw. of electric power. All branches of industry need high-frequency current, but high frequency is still a luxury for us. So far it is being used for delicate operations in machine-tool building, etc. The rates of industrial development and the needs of industry are so great that there is not enough electric power. And this is why our metallurgy has not yet become an electro-metallurgy.

"If we vault mentally over decades and take a peek into the time when the controlled thermonuclear reaction producing helium from hydrogen will have been achieved and nuclear power stations will have helped to produce an abundance of electric power, we shall be greeted by our old and true friends—the electric motors, the groundwork for which was laid by Faraday as early as the 19th century. Of course, we may strive to develop semi-conductor devices, electronic computers, etc., but the young people of today, the future engineers and technicians, must clearly understand that no progress

in electrical engineering is possible without improving the existing electric motors. Here is something worth racking one's brains over: what can we do to increase the capacity of our machines and raise their efficiency? Where can some machine or other be used to greater advantage? What types of current should be used in each particular case?

"In other words, we shall have to make the most of all the possibilities of the expanding electric power resources—the backbone of industry. High-frequency power will also win an honorary place in electrical engineering within the coming decades.

"What makes high frequency so interesting? It makes it possible easily to change the parameters of the current and any of its properties—tension, strength and quantity. For example, the highest possible tension is the most profitable for the electrification of railways. But this means that very complex equipment for transforming the current will have to be installed on electric locomotives. High-frequency apparatus is the answer to this. The compact HF instruments to be developed in the nearest future will serve as the new and convenient link between the high-voltage current supply line and the motors of the electric locomotive.



The design of the artificial sun was essentially simple.

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"But I seem to have run away with myself," said the professor with a smile, and began to talk about things everybody knows today. "Let us touch upon a few more fantastic forms of utilizing high frequencies.

"The life-giving rays of the sun, always admired by poets, appear much more prosaic to the physicist who sees them as a stream of easily measured electromagnetic oscillations. 'Nine volts per centimetre,' he says as he looks at the instruments recording the 'voltage' of sunlight on a bright noon. But a high-frequency generator can produce hundreds and even thousands of volts per centimetre. What is the sun? Only two kilowatts of power per square metre. But a HF generator makes it possible to concentrate scores of thousands of kilowatts of power. These rays are more terrible than the heat rays of the Martians described by H. G. Wells. But the most remarkable thing about it is that the recently conducted experiments have made the development of industrial machines, for example, for crushing the hardest rock feasible in the nearest future.

A Ray That Pierces Mountains

"Say, we have to drive a tunnel through the Pamirs or the Himalayas; we want to build a direct road through the mountains from India to Siberia. A small, 50-ton cistern with a radiating grid in front sets to work. It approaches a cliff and a stream of its light clearly outlines the rocky wall. Heated to a high temperature the latter begins to crumble, broken up by temperature stresses and blasted by the water contained in it turned to steam. The temperature continues to rise, the rock melts and a stream of lava begins to flow, but the ray resembling a gigantic acetylene burner keeps moving ahead. The high-frequency 'mole' burning through the rock works without people. The operator only watches the remote control panel.

"In the history of man, including that of engineering, development usually proceeds, figuratively speaking, along an ascending spiral. It is not the first time man is using fire—high temperature—to destroy gigantic rocks. This method was known even in ancient Egypt. Mechanical drilling appeared

later, and explosives began to be used for drilling wells. Today engineering is resorting to flame again, although on a higher level. It is a stream of flame coming out of the nozzle of a jet engine that is directed at the rock.

"Other experiments, too, are being conducted: oxygen is fed into a steel pipe and the other end of the pipe is set on fire. It happens that wells can also be drilled with the flaming end of the pipe. But the most tempting of the new methods of drilling or tunnelling is the high-frequency method. Even with the present-day quantities of electric power produced and even with its rather high cost this method is very promising, and a group of scientists in the All-Union Coal Research Institute is working on this problem.

"In the total stream of electric power the share of HF current will increase in the 21st century, I am certain, to 10 and perhaps even to 25 per cent and will win in our life the same place as is held by direct current today.

"The idea of using valvular high-frequency generators to harden steel was for the first time voiced and carried out at the Leningrad Svetlana Works in the 1930s. The Americans caught up this Soviet technical idea and were able to surpass us in the number of HF plants, as well as in their capacity which is now over a million kilowatts. However, we shall soon be able to catch up with and outstrip the Americans in the practical utilization of high-frequency currents.

"By the end of this century metal cutting will be almost completely replaced by punching. Numerous articles—from huge forgings to tiny bolts, nuts and gears—will be 'pressed out' of metal heated by HF current.

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How a Sun Will Be Hung Over the City

"Some night, about 30 or 40 years from now the Muscovites will see an enchanting sight. It occurs to me this may happen on the 2010th New Year's eve when humanity enters the third millenium. An artificial sun created by man and lifted to an altitude of 20-30 kilometres will flood the City of Moscow and Moscow Region with its light. It will take millions of kilowatts—the capacity of the Stalingrad Hydro-Electric Power Station on the Volga—to give the metropolitan region the gigantic street light. No, this will be neither a lamp nor a projector on a balloon. Electromagnetic rays sent up by mirrors from four high-frequency stations in the environs of Moscow will focus high above Red Square and make the heated molecules of nitrogen and oxygen shine. Even the losses in the work of the artificial sun will not be losses in the general resources. The nitric oxides formed in the flame of the artificial sun will fall

on earth with the rain and wind. And these oxides are a valuable fertilizer."

We asked Professor Babat to tell us how the idea of kindling a high-frequency "sun" came about.

The scientist reached out and took a thick book in a dark leather binding from his desk.

"It is a diary of the war years," he said in response to our inquiring look.

Thumbing through the pages he found the necessary notes.... It was during the grim days of the late autumn of 1941. The laboratories had to be operated days on end, many people spending their nights there, too. But there was still some electric power in the city, and the experiments could be continued. Engineer Babat was in a hurry to finish the work he had begun. He probably stayed in the laboratory longer than anybody else. It was then that a flickering electric flame at last flashed over the metallic petals of the instrument like a flower that had just opened.

The tiny sun lighted up the scientist's laboratory, and the inventor's heart has retained this flame for ever. G. Babat fed the installation not the usual "even" current, but a modulated current. Simply speaking, he passed it through an engaged radio receiver. And submitting to the oscillations of the electric current the flame flickered, now growing larger and now sharply diminishing. It became, as it were, a membrane which made the adjacent air vibrate and generated sound waves.

The flame sang:

Let noble rage
Surge up like a wave...

while its inventor stood enchanted and listened unable to take his eyes off. Singing flame. Singing sun....

The song roared with steel and hatred for the enemy. It burned like this fire that you cannot touch. And suddenly Heine's impassioned words—

Oh sun, you wrathful flame!...

flashed into the mind.

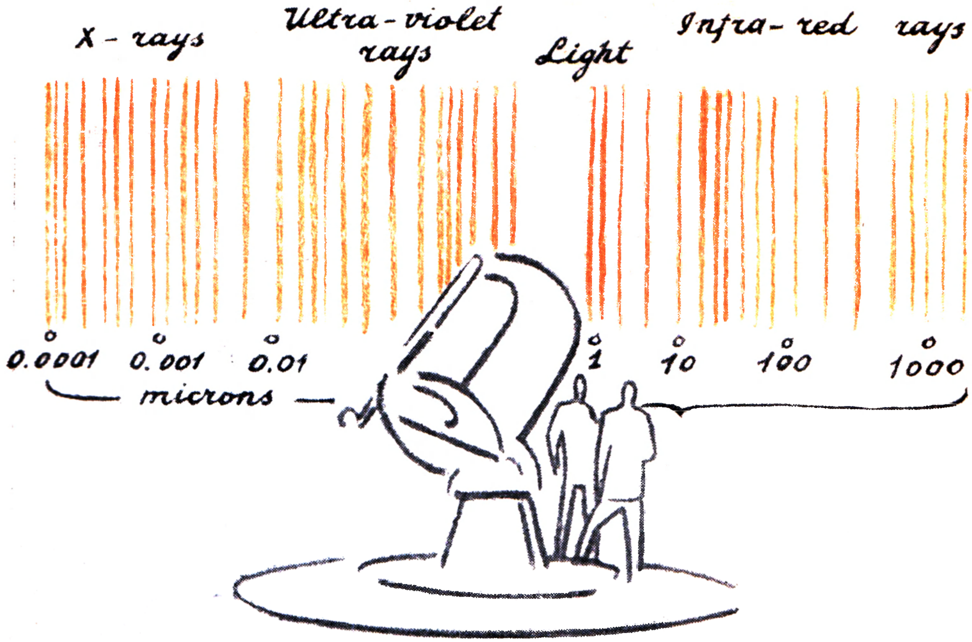
The singing flame was still before our eyes but Professor Babat was already giving us new examples of using high frequencies. He was telling us about the 21st century telephone and the single system of electric communications that will cover the earth and will make it possible for two persons at different ends of the world to get in touch with each other quickly and talk things

over. Man will relinquish the cumbrous mechanical apparatus of modern telephone exchanges which limit the number of possible connections. The mechanical searchers will be replaced by the practically eternal semi-conductor instruments—the "nervous ganglia." A semi-conductor switchboard for several hundred telephone subscribers will be about the size of a shoe box. Automatic amplifiers will enable us to talk, for example, with South America by calling directly or indirectly (the system will have numerous crossing channels) any "nerve cell," any house switchboard in any country. The high-frequency method will make it possible to have practically any number of channels for communication.

The Second Window onto the Universe

Vitaly Ginzburg, Corresponding Member of the U.S.S.R. Academy of Sciences and versatile scientist known, in particular, for his contributions to radioastronomy, began his story with physics rather than astronomy.

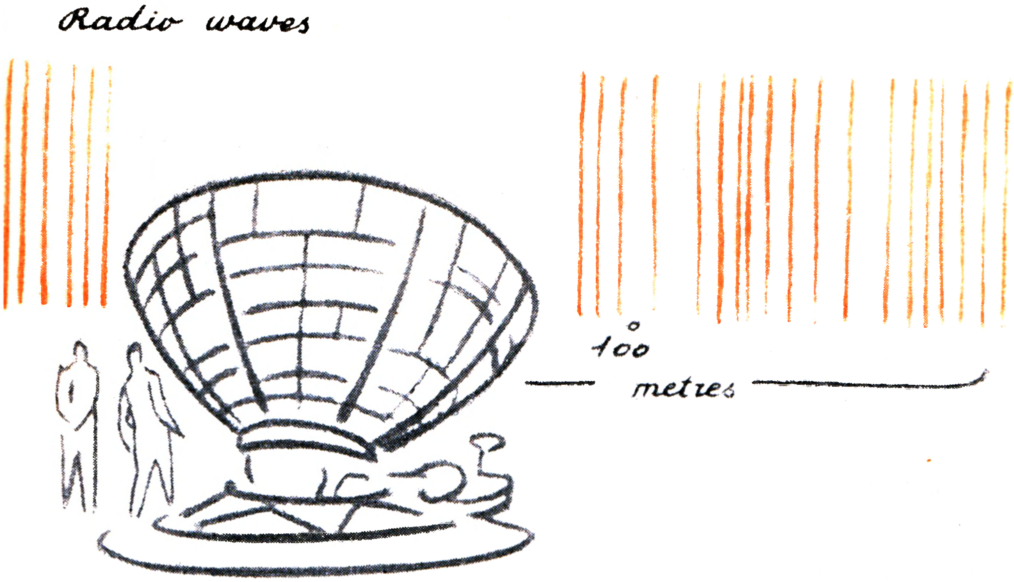
"Physics is radioastronomy's mother," he said, "and we are all watching its achievements with great interest. Speaking about its future, I believe mastery of controlled thermonuclear reactions to be its problem No. 1. Man will learn not only to set off hydrogen bombs but also to regulate the production of energy taking place during thermonuclear reactions. If we succeed



in carrying a slow hydrogen reaction of splitting and synthesizing light atomic nuclei into effect we shall solve the problem of fuel for ever.

"And now about problem No. 2. This problem is connected with astronomy and many other sciences that are helping it. It began to be solved by Soviet scientists with the triumphant 1957 event. I am referring to the launching of the artificial satellite of the earth. The first satellites went into orbit during the last International Geophysical Year. I am sure that in the year 2010 several satellites will be flying at different altitudes around the earth. It takes them only one and a half to two hours to run around our planet. The higher the satellite and the farther away it is from the earth, the more slowly it moves across the sky. A satellite about six and a half earth radii, i.e., about 40,000 kilometres, away from the centre of the earth will be of particular interest. If we launch it above the equator in the same direction in which our planet is revolving and impart to it the same angular velocity of rotation that the earth has, the observer on the equator will see it suspended at one point of the sky. This is convenient for continuous observation.

"Soon the satellites will be used for the most diverse scientific and technical purposes—meteorological observations, radio rebroadcasts, telecasts, etc.



The second window onto the world is much wider.

The satellites will once more help to ascertain the general theory of relativity. Does time really run more slowly on a rapidly flying object? Now we can check up on it experimentally.

Artificial Satellites and the Theory of Relativity

"The sun and the stars send ultra-violet and soft X-rays on earth. But the terrestrial atmosphere, like a filter, retains the roentgen and ultra-violet radiation. The instruments on satellites investigate these radiations in a much purer form.

"It is important for astronomers to know the summary brightness of constellations. But try and ascertain it when the night sky itself and the atmosphere to an altitude of several hundred kilometres are luminous. This means we have to rise still higher, and it is just what the scientists will do in the nearest future when most diverse satellites orbit in the uppermost layers of the atmosphere.

"Today there are three so-called 'windows of transparence.' The electromagnetic waves penetrate to us best in the optical range; they are rays with a wave length of 4,000-8,000 angstroms, or from 0.0004 to 0.0008 mm. Only in such waves have we studied all of the universe until recently. The second 'window of transparence' in the radio wave part of the spectrum is much wider. Our atmosphere is transparent to radio waves from 2 centimetres to

about 100 metres. Eight-millimetre waves also pass through it very well. Our atmosphere is not transparent to all the other parts of the spectrum of electromagnetic oscillations. But by sending radio apparatus up on a satellite it is possible to receive much longer radio waves.

"The third 'window' is for hard radiation coming from outer space. It is the cosmic rays.

"For thousands of years man has looked from the earth into the abyss of the universe only through the narrow 'optical window.' The time has now come to make use of the second and wider 'radio window' for this purpose. Today we can safely say that much greater vistas open up before us through the 'radio window' than do through the 'optical window.'

"But, of course, our radioastronomers have but scarcely looked out of this window.

"You know radioastronomy is one of the youngest sciences of our time. It began to develop essentially only since the Second World War. During this short period we have obtained such information about the universe through the 'radio window of transparence' as we could not possibly have obtained by any other means. Radioastronomy has not replaced optical astronomy but, on the contrary, has helped the latter by peering into such spheres and seeing such things as you could not see even through the most powerful telescopes.

"Let us take our sun. It is a dense gas sphere with a vast incandescent atmosphere—the sun's corona—over it. It has a temperature of millions of degrees but its optical brightness is relatively low—only 0.00001 of the sun's brightness. In itself the corona is about as luminous as the full moon. The sun's corona can be studied by the usual optical method only during a total solar eclipse when the blinding disk of the sun is obscured by the moon. Eclipses occur rather rarely and last but a few minutes. It stands to reason that by this method we cannot obtain full information about the corona. It is different with the radioastronomical method. All the radio emanations of the sun on metre waves come from the corona. It has been possible to establish that the atmosphere of the sun stretches for about ten radii around this star closest to the earth, covering one-tenth of the distance between them.

"While studying the radio emanations of our galaxy which is a gigantic stellar system, the scientists have arrived at the conviction that the galaxy is enveloped in an enormous gaseous cloud which can be seen in radio waves but is invisible to ordinary telescopes.

"Let us assume that a creature that can see in radio rays has appeared side by side with us on earth. Let it not seem too fantastic to you because radar, for example, does have such 'vision.' To such a creature the whole of the surrounding world would appear unrecognizable. To begin with, it would be astounded by the blinding brightness of the sun. The optical spectral analysis shows the surface of the sun to have a temperature of 6,000 degrees, whereas the radio emanations of the sun's corona correspond to a temperature of 1 million to 2 million degrees.

World Visible to Radio Eyes

"We easily find the Milky Way—the luminous band of stars—at night. In the day-time all stars 'fade' in the bright rays of the sun and we do not see them. A creature with radio vision would see several suns both day and night. It would perceive the so-called radio stars—sources of radio emanations invisible to the naked eye—burning in the black depths of the universe. There are dozens of them, to mention only the bright ones, although all in all thousands of 'radio stars' have already been discovered. In radio rays some of them are as bright as the sun, although they are scores and even hundreds of millions of light years away from us. Of course, you know that a light year is the distance traversed in one year by a ray of light travelling at the rate of 300,000 kilometres a second.

"But the sun would never get lost amid these heavenly 'radio beacons.' And do you know why? Because they all 'shine' evenly, like a candle on a still night, whereas the sun does not.

"The radio brightness of the sun varies very greatly. In the optical range its luminosity hardly changes. Only sometimes there are more spots on it. But the intensity of the sun's radio emanations may sharply increase—10,000-fold—and then the radio telescopes seem to choke on the squall of splashes of solar radio emanations. Within a few minutes the storm may die down. The sun seems to breathe.

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"We have talked about radio vision as a dream. I think that by the 21st century man will acquire full and very keen radio vision. Let us imagine ourselves at a powerful radiotelescope in a 21st century observatory.

"You take a look at the chart, dial the code, and a radio map of the requisite part of the sky appears on the screen. You look for Cassiopeia, the ultra-new star of the year 369, or what is left of it, to be exact. In 369 it exploded. The tufts of gas, the products of the explosion, have formed a neb-

ula. Then you find a bright 'radio star' in the constellation of the Swan (Cygnus). Two gigantic galaxies that collided and now permeate each other are located there. The powerful radio emanation that arose during the collision enables us to observe this cosmic catastrophe that is taking place at a distance of 280 million light years away from us.

"Of course, we must not understand the word 'catastrophe' in its direct and literal sense. We must not imagine colliding stars and planets as running full speed into each other or regard the radio signals reaching us from there as the roar of these cosmic collisions. In the stellar galaxies the stars are extraordinarily far from each other, the closest neighbours being divided by distances measured in light years and even dozens of light years. With such dispersion collisions between stars in these interpermeating galaxies are uncommonly rare, although not impossible. Similarly two dispersed charges of shot may go through one another without the individual pellets colliding with each other.

"It is different with the dust and gas clouds forming part of the colliding galaxies. Their interpenetration is undoubtedly attended by innumerable collisions and close interaction of their particles. It is most probably they that serve as the source of the radio emanations which reach us.

"This grandest natural phenomenon was discovered with the aid of a radiotelescope which pointed out the source of powerful radio emanations. Only later was it possible to make it out through a powerful telescope. In the future the radiotelescope will probably make it possible to 'get a good view,' even of some details of this grandest of all encounters ever to occur in the universe.

"The optical telescopes have reached the limit of their potentialities. They 'see' no farther away than 2 million light years, whereas radiotelescopes bring us information about even more remote nebulae.

"The mirror of the largest optical telescope in existence has a diameter of 5 metres. Still larger mirrors will be made. A telescope with a 6-metre mirror will probably soon be built in the U.S.S.R. But there are still many opportunities for making better use of the existing telescopes. Thus electronic optical devices increase the sensitivity of telescopes to such an extent that a five-metre telescope yields a magnification which ordinarily only a ten-metre telescope would be able to produce.

"Radiotelescopes are as yet unable to produce so exact an image of the details as do the optical telescopes. To obtain the same degree of precision with which details can be seen through a five-metre optical telescope we

would have to build a radiotelescope with an antenna 10,000 kilometres long, which is impossible. Nor is there any point in doing it. The continuous antenna—the radio mirror—can be replaced by a chain or network of antennae connected with the observatory and interconnected by a radio relay.

Mirror with a Diameter of 10,000 Kilometres

Such a chain could be stretched, for example, between Moscow and Gorky. Gradually several such chains could be connected into a single radiotelescope network very much like a high-voltage grid. A gigantic radiotelescope will thus come into being. I think that by the 21st century it will be possible, in principle, to build a single radiotelescope network covering all of Europe.

"Let us go back to our 21st century observatory where the innumerable radio signals caught by the antennae—the fragments of the immense radio mirror of our wonderful telescope—are gathered. On the screen before the operator is a radio picture of the sun. Underneath it are the words '1-m. wave.' The sun is large and it shines brightly. You press a button and the telescope begins to receive 60-cm. waves. On the screen the sun appears somewhat smaller. This means that the 60-cm. waves are emitted from regions closer to the centre of the sun. The operator turns on the 10-m. band, and the sun immediately increases to three times its size. With the aid of this telescope the astronomer not only studies the intensity and composition of the radio waves emitted by heavenly bodies but also finds out where they are born.

"But observing the radio emissions coming to us from outer space is not all. Radioastronomers have decided not only to catch the waves that break through to us but also to send beams of waves to the other planets and feel their surface, as it were, with sensitive fingers. At the end of the Second World War radars in Hungary and the U.S.A. sent the first radio signals to the moon and recorded the radio echo that returned to the earth. Even before the radio-location of the moon was effected the late Academician N. Papalexi elaborated methods of radio-locating it.

"A gigantic radiotelescope with a 80-metre metal antenna-mirror was recently built at Jodrell Bank, England. A detailed study of the moon requires even larger telescopes. And not only of the moon at that. By changing the length of the wave we send out we shall be able to obtain a section of the atmosphere of any planet—Venus, Mars, Jupiter, etc.

"It is noteworthy that the radioastronomical methods make it possible to peer not only into the future of our galaxy but also into its past. The thing is that our universe is expanding like an exploded bomb. The mean density

of matter in the universe was much higher 5,000 million years ago than it is today.

"The hypothesis that the universe is expanding originated when the so-called red displacement in the spectra of distant galaxies was observed. If a light-emitting body moves rapidly away from us, the lines in its spectrum will be displaced towards red. It was the red displacement in the spectrum of the distant galaxies that served as the first reason for inferring that the universe was expanding, this fact being considered firmly established today. Physicists and astronomers now no longer speak about the expansion of the universe abstractly but on the basis of conclusive scientific data.

"What is the nature of this expansion and what laws govern it? How are galaxies and individual stars formed? I think we shall have the answers to these questions long before the coming of the 21st century."

JAUNTS EXCURSIONS TRAVELS

On Land, at Sea and in the Air
Through 21st Century Moscow
Model of the Year 2010
A Picture of the Future School
Magnetic Photographs and Films
Siberia Through a Stratoplane Window

Let us imagine that a person who lived in 1910 suddenly found himself in our midst in 1960. Yes, quite suddenly. He went to sleep in 1910 and woke up in 1960. We should undoubtedly receive this unusual guest with all possible hospitality. Just think of all the amazing things he would see during the very first hour spent in our time.

Most wonderful electric lighting. Of course, he must have seen such lighting in rich homes but he never thought he would see it practically everywhere.

Astounding radio receiver. A small box with a magically winking green eye of the signal lamp and a scale with the names of cities. Is this not a miracle, to be listening here in the room to the music played at the Milan Opera House?

One more marvelous box—the TV set. A greenish screen on which clear images move, act and speak. It is the fancy of the most unrestrained fantasts incarnate. Unbreakable glass on the desk made of some wonderful material—plastic. The desk-set, ash tray and calendar-base are all made of a similar wonderful material.

Even the usual fountain-pen which has replaced the quill and steel pen would cause this 1910 person, who suddenly found himself in our midst, to display a very lively interest.

This person would certainly not stay long in his hotel room but would immediately start wandering about the streets and would want to travel around the country to take in with keen admiration all that is new to him.

Asphalted streets and squares would be the first thing to strike the eye of this person accustomed to cobble-stones and stone blocks.

A bright rainbow of neon lights. "Can it possibly be the northern lights that engineers have stolen from the sky and have confined to glass tubes?" our traveller would think.

He would walk into a shop. Capron stockings, plastic buttons, shoes with microcellular soles, electric refrigerators and vacuum cleaners—no end to the things that did not exist 50 years ago but could now be found in every home.

He would go to a wide-screen cinema and would marvel at the thing into which the modest invention of the Lumière Brothers has developed.

While flying over the country aboard the TU-104 jet airliner, this man, who in his time saw the leaps rather than flights of the contraptions made of cloth and sticks, would exclaim: "At last man has conquered the sky!"

Could the visitor from the year 1910 foresee all that surprised, amazed and appeared new to him in 1960?

A good deal, but not all.

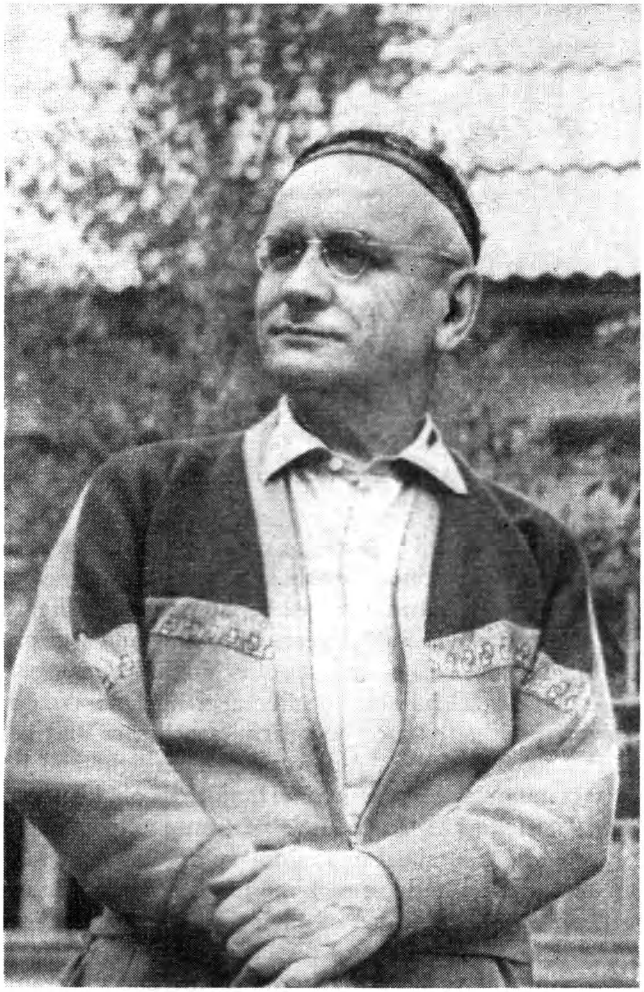
An aircraft specialist might have foretold him the triumph of airplanes—heavier-than-air flying machines.

A physicist might undoubtedly have foreseen the coming of sound, colour and wide-screen films.

A transport engineer might have predicted in general outline the changes the automobile would undergo in the course of 50 years.

As for television, though, probably no person could have predicted it at that time, since a number of fundamental ideas, discoveries and inventions, without which the transmission of moving images over a distance is impossible, were lacking. At that time the possibility of transmitting moving images over a distance was mere fantasy, very much like the idea of the possibility of transmitting objects or living beings by radio over thousands of kilometres would be today. Not a single scientist of our day would take the liberty of asserting that this will ever be achieved.

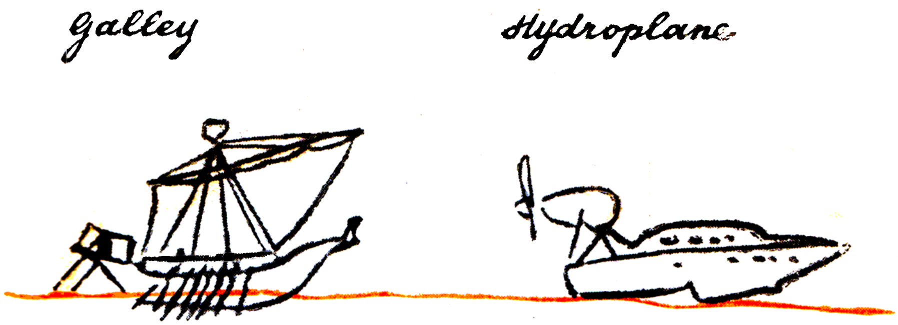
This book contains no ideas that have not been prepared by the present-day state of knowledge. Nor are there any in this chapter devoted to the first impressions, trips and travels of the people finding themselves in the world 50 years hence. As for us, we could not help going on these trips or making these journeys, as we believe no one, finding himself like us in the 21st century, could.



On Land, at Sea and in the Air

We began our excursions with the study of Vasily Zvonkov, Corresponding Member of the U.S.S.R. Academy of Sciences. We were interested in the means of conveyance we should be able to use in our jaunts and journeys through the 21st century world. It was early morning.

"The morning hours are the best time for work," said the scientist. "I have been getting up early all my life and therefore feel that compared with all other people I have two or three extra hours every day. Just think of all the years that adds to your life!"



A fast ship tends to lift its hull out of the water;

He laughed merrily. Then his eyes grew stern, even cold. He put his hand on a stack of scientific journals and began:

"Envy is a harmful emotion; it shortens one's life. And still I cannot but envy those who will live 50 years from now and will profit by all that science and engineering will be able to offer at that time.

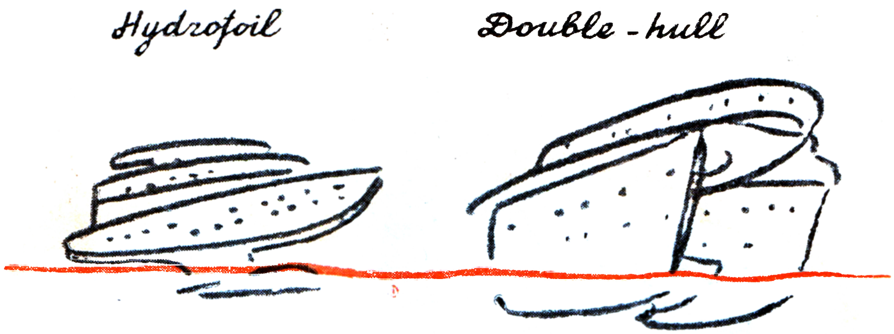
"And they will be able to offer a great deal. We have grown accustomed to living amidst the most wonderful machinery and barely notice the things the machines do for us. And yet machines light and heat our homes, enable us to communicate over many hundreds of kilometres and facilitate our work. I am working in the field of transport machinery and I must say that they, too, have attained extraordinary development.

"Recently my business took me to America and I travelled back to Europe by the *Queen Mary*, one of the world's largest and most comfortable ships. It is a ship of 81,000 tons displacement and 200,000 h.p. engines, i.e., the capacity of a large heat and power plant. The ship ran into a storm. She was thrown about like a log, she creaked and made one feel she was going to break up at any moment. But she moved just the same, and moved well, making about 60 kilometres an hour. It took us only about 5 days to cross the Atlantic.

"But what about the future, say, 50 years from now? How long will it take to make that crossing?

"I think it will take only about one-fifth of that time. But for this purpose the shape of ships will have to change radically.

"The resistance to the movement of ships in water is made up of two factors—the resistance of the water and the resistance of the air. The former is the main factor today.



a two-hull ship does not have to do it.

Speeds Will Keep Increasing

"How can we reduce it? Try and take the body of the ship in motion out of the water. To be sure, everybody must have seen how swiftly a hydroplane moves, leaping over the crests of waves like some fantastic flying fish. Its body is wide and flat, and it glides over the surface of the water like a very large ski. But no hydroplanes the size of the *Queen Mary* or even one-hundredth her size have been built as yet because of a number of technical difficulties.

"Of late so-called hydrofoil ships have attracted general attention. While the ship is in motion the foil which is located deep in the water under the body of the ship experiences a lift similar to that experienced by the wing of an aircraft in the air. The foil itself remains underwater but lifts the whole body of the ship. Such ships, but also of small draught, are already plying the Volga. But there are no large draught ships of this type as yet.

"It is quite possible that the problem of reducing water resistance may be solved without lifting the body of the ship but by radically altering its shape. It will be observed that even the Greek triremes had almost the same shape as the ocean liners have today. But if we cut the body of a modern ship along its main plane of symmetry and then join the halves again by their outsides"—with a few strokes of a pencil the scientist drew a sketch—"placing either screw or water-jet engines in between the halves, the drag of such a ship will diminish considerably. I tested a model of such a ship. My approximate calculations show its tractive force to have increased 45 per cent. The fore and aft waves also diminished shaprly. It should be noted that the waves formed by a ship represent the wasted power of its engines.

A Ship Turned Inside Out

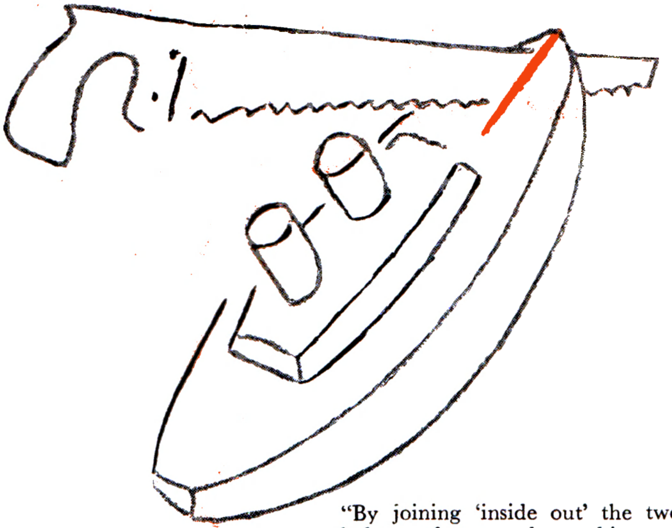
"If the body of the *Queen Mary* were reconstructed according to the above principle, the ship might cross the ocean and arrive in Europe on the third

rather than the fifth day. In the future the people will probably travel by such double-hulled ships.

"I do not think I shall go wrong if I say that the ocean-going passenger ships of the turn of the century will be submarines. Of course, the increase in the ship's speed will considerably reduce the annoyances caused by stormy weather. But it is much less trouble and much more interesting to submerge and continue on the way underwater. Passenger and freight submarines will sail the year round under the ice of the polar seas connecting the two continents by the shortest route.

"We must make a special point of the engines of future sea- and ocean-going ships. They will no doubt be atomic engines.

"What is the tremendous advantage of atomic energy over coal and oil products for the transport? To begin with, it is enormous energy released during the splitting of uranium, one kilogram of uranium-235 having the calorific power of about 2,500 tons, i.e., two trainloads of anthracite.



"By joining 'inside out' the two halves of a modern ship cut lengthwise we shall get the body of a ship of tomorrow," said V. Zvonkov.

The golden rays of the sunset illumined an unusually shaped ship racing along the mirror-like surface of the ocean.

"This means that the ships of the future will not have large bunkers for coal or tanks for fuel which take up close to one-third the displacement of modern freight ships. It follows that their effective load-carrying capacity will increase at least by one-third.

"The question of using atomic reactors on ships has now been practically solved. According to the calculations of the Institute of Overall Transport Problems of the U.S.S.R. Academy of Sciences, the carrying capacity of atom-powered ships, even in their present incipient stage, is 20-30 per cent higher than that of ships driven by steam turbines. The costs of transportation by atom-powered ships will be much lower than those by steam-turbine ships. Ocean-going freighters will have a carrying capacity of 100,000-200,000 tons and a speed of about 120-150 kilometres an hour. These ships will be well streamlined both above- and underwater. It is precisely the atomic power plants that will impart to the ships the speeds which we have already mentioned and which appear so fantastic to us today.

"However, transoceanic passenger traffic will be carried on by super-speed jet planes rather than passenger ships.

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Railway Dreadnoughts

"Now about the railways, the form of transport carrying big cargoes over long distances. I am absolutely sure that in the very nearest future we shall be able to travel by trains of higher carrying capacity. I am referring to the broad-gauge railways. The Soviet standard gauge of 1,524 mm. was proposed by Melnikov, one of the engineers who built the Petersburg-Moscow Railway. It can no longer satisfy us even today. A 3-5-m. gauge will enable us to build wagons of much higher carrying capacity and use locomotives of 40,000-50,000 h.p. to ensure a speed of 250-350 km/hr. It will be much easier to equip such locomotives with atomic reactors. As is well known, it is only the problem of shielding that prevents atom-powered locomotives from being put on the Soviet railways today. Several countries have already designed such locomotives. Even senior students of higher technical schools make such designs.

"You want to know if it may not be expedient immediately to change to an even wider gauge? In all probability the question of the necessity of building transcontinental railways with such a gauge will some day arise. But this will occur either in the middle of or after the 21st century, perhaps 100-150 years from now.

"The importance of pipeline transport has been growing of late. There are reasons to believe that this form of transport will attain greater development for the transportation of mass cargoes—oil-products, cement, grain, flour, etc.

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Motor Vehicles Excluded from City Traffic

"A few words about the city transport.

"During the last few decades the fleet of motor vehicles has sharply increased all over the world and this has begun to transform the convenience of motor traffic into its opposite. In New York I chanced to observe the beginning of this most unpleasant phenomenon. In some parts of the city motor traffic is so heavy that it is impossible to get through. Vehicles move at the speed of pedestrians. In many streets there is only one-way traffic because the cars parked at the curbs render two-way traffic impossible. Under such conditions you can hardly take advantage of any opportunities which the powerful modern cars offer for rapid traffic.

"The vast fleet of personal cars stays inevitably idle. These cars waiting for their owners block the streets and reduce their traffic capacity still more. This is why I think that at the end of the 20th century cars will be generally forbidden entrance to large cities. You reach the outskirts of a large city and that's that; please, park your car and use public transport to get around within the city limits.

"The future out-of-town gas-turbine jet-propulsion cars will be able to develop a speed of 250-300 km/hr.

"Of course, this will take place only after the reconstruction of at least the main highways. They will cross each other, as well as other roads at different levels.

"What will the main features of city traffic be then? In cities and suburbs they will most probably be moving pavements and helicopters.

"Imagine three ribbons of parallel horizontal escalators moving at the rate of 20, 40 and 100 km/hr respectively. These escalators are moving in both directions along all streets. To step on one of them or change from one to another, is as easy as stepping on an escalator of the Metro.

"For convenience, I think, these moving pavements will have chairs, benches and automatic booths selling soft drinks, ice-cream, candy and cigarettes (although, I have an idea, by the 21st century people will have given up this nasty and harmful habit of inhaling the smoke of smouldering dry weeds

wrapped in paper tubes. If there are any smokers at all, they will constitute a survival of the past, an anachronism).

"I believe the first such lines of moving pavements should appear in the streets which have the heaviest traffic or steep ascents and, hence, are the most hazardous for pedestrians. It seems to me it might be expedient to start such lines now, say, between the Nogin and Dzerzhinsky squares in Moscow.

"There can be no doubt that moving pavements will come into being. In the beginning they will replace the other forms of city traffic only in certain streets and then they will merge in a single, well-thought-out system serving the centre of the city. This will be the time when the motor- and trolley-buses shall have been forced out to the outskirts as the trams have been forced out there by now. Later the outskirts will also be encompassed by a network of moving pavements. The moving pavements may even run as far as the satellite towns and thus supplant the suburban electric railway.

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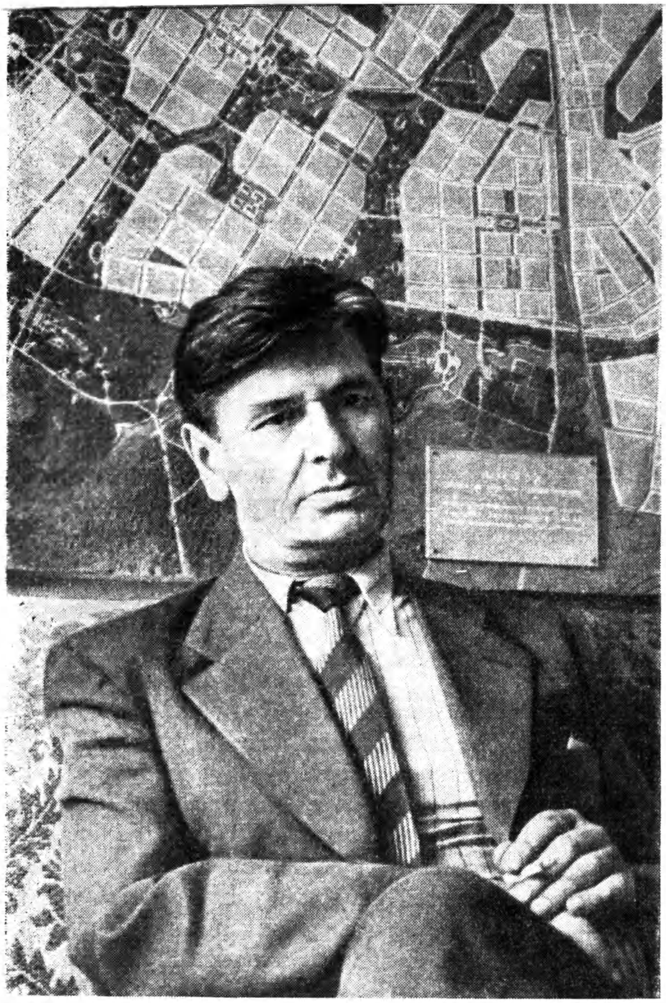
"Now let us go up in the air. I have travelled a great deal and have had to fly a lot. My last flight across the Atlantic—from Paris to New York—on a Superconstellation four-engined, propeller-driven plane, took only 17 hours. It was a fine and very comfortable plane, although, frankly speaking, it rolled and pitched very little less than the *Queen Mary*. And only once in my life did I really enjoy my journey. It was my flight on the TU-104, the fine high-speed airliner which I consider the forerunner of future aviation. We flew at an altitude of 10,000 metres and covered the distance between Prague and Moscow in less than two-and-a-half hours without any shaking or pitching. We actually did not feel we were flying. It was a wonderfully comfortable trip.

"The future of aviation? Undoubtedly atom-powered aircraft, passenger flights at altitudes of 15,000-20,000 metres and speeds of up to 5,000-6,000 km/hr.

"Of course, we have only touched upon the most general, major problems. Nor can the future be foreseen in detail. All we can do is to point out the general trends in its development."



Through 21st Century Moscow

There were five of us in the room—two journalists, a stenographer, Nikolai Yevstratov, Director of the Institute of Moscow's General City Planning, and the map of future Moscow, as yet silent behind a cream-coloured curtain. But we had a feeling that it, too, would have something to say in our conversation. In the meantime it was Yevstratov who did the talking. He was speaking unhurriedly, thinking over every sentence and being very careful not to say anything for which his stern colleagues may dub him a fantast or dreamer.

"Cities change their face extremely slowly," said Yevstratov. "I think that even today Honoré de Balzac could roam for hours through the Paris by-streets and alleys in which his heroes lived 100 years ago and he would hardly have to make any changes in his wonderful descriptions. Nor did the face of pre-revolutionary Moscow change for centuries.

"The following is a characteristic case from the history of Russian town-building. About 1702-1706, in expectation of the offensive of Charles XII, Peter I built bastions around the Kremlin and Kitai-Gorod (a part of Moscow). As is well known, Charles XII did not advance on Moscow but went to the Ukraine where Peter I defeated him near Poltava. But the Moscow bastions continued to block the main roads: the greater part of present-day Revolution Square, part of Sverdlov Square and Teatralny Proyezd were taken up by earthen fortifications. So great is the power of inertia in town-building that those bastions had existed for more than 100 years and were razed only in 1823.

Old Age and Youth of a Great City

"It is quite different with present-day Moscow which has changed beyond recognition in the last 40 years. Recently I asked a man, who had not seen Moscow since before the Revolution, how he liked the city. Since this man is a poet he answered with a poetic comparison. 'What can you say about a woman you loved but have not seen for 40 years? You look at her old and wrinkled face and only here and there you seem to catch the familiar features of her beautiful youth. I have not seen Moscow for 40 years, and looking at the city's rejuvenated and beautiful face I find only here and there the former wrinkles which I remember so well.'

"Yes, in the last 40 years Moscow has changed beyond recognition. The city will develop at an even faster rate during the coming 10-15 years. Today it covers an area of about 35,000 hectares; by that time its area will increase to more than 60,000 hectares. Whereas today close to 70 per cent of Moscow's population lives within the limits of the Kamer-Kollezhsky Val (Rampart), by that time 75 per cent of the population will live outside its limits."

At this point the cream-coloured silk veil was removed from the face of the fifth "interlocutor." The map of future Moscow appeared before us covering a whole wall in Yevstratov's study. We recognized our capital by the familiar bends of the Moskva River, the radial arrangement of her streets and the polygon of the Kremlin in the centre. And still it was not the Moscow we knew. The city had greatly expanded by incorporating the

recent suburbs. Almost one-third of this new Moscow's area was covered with green and blue spots of parks and reservoirs. Not one but five ring thoroughfares encompassed the rays of her streets. Yevstratov took a nickel-plated extensible pointer and, as though obeying the movements of this glittering wand, the various details of the plan came to life before our very eyes.

"In recent years the territory in the south-west of Moscow will become an integral part of the city. Cheryomuchki, sections of Lenin Prospekt and the area of the ZIL Settlement will be among the most modern and well-appointed parts of Moscow.

"The city limits will also move in the north towards Khimki. Today Moscow has been enlarged to include the towns of Babushkin, Kuntsevo, Perovo and Tushino as well as all the minor settlements within the radius of the new Moscow circuit highway. Housing construction will soon begin in the area of the Khimki River Port, the out-of-town settlement of Khovrino and the area of Mazilovo. In the immediate future Kuntsevo will become one of Moscow's most beautiful districts.

"Now you want to know what the population of this vast city will be like. Today Moscow has a population of 5,032,000. This figure will not change very much in the future.

"Speaking about future Moscow we must mention the satellite towns which, located 50-70 kilometres from Moscow, will be closely connected with it.

"Yakhroma on the Yakhroma Reservoir will apparently be one of these towns, Krasnaya Pakhra another.

"Moscow will be a beautiful green city, a garden city.

"Work of irrigating the territory of the South-West and of planting greenery on it will begin in the nearest future. A vast forest-park will be laid out in this area. The small Setun River will be transformed into a chain of blue lakes, the mirrors of the lakes sparkling on the sites of the present-day ravines. The areas of the Tatarovskaya and Strogino flood-lands will also be transformed into a beautiful forest-park in the nearest future.

"You must know that it takes many years to lay out parks and forest-parks. 'Water in the morning, clip in the evening. And so for 100 years' is what the English say about the secret of cultivating the famous English lawns. In the streets of Moscow we are now planting adult trees and saplings. But we are not relying merely on the new plantations. We are aiming to make use of the now vacant territories of the Izmailovo Forest-Park.

"Greenery will be planted in most of the city's streets. Many people know

the streets through which 'Ring B' runs. Boulevards with at least two rows of trees will be laid out on each side of these streets.

"The next ring of boulevards will run along the line of the Kamer-Kollezhsky Val. The fourth ring will be still wider. These ring thoroughfares will cross the radial streets at different levels with traffic running over and under bridges.

"Today Moscow has a 10-kilometre forest-park belt. A scheme for the development of a 50-kilometre afforestation belt has been elaborated by a decision of the government. All the vacant lands in this belt will be afforested. This 50-kilometre forest-park belt will serve as a place of rest and recreation for the population. New summer residences, sanatoriums, and an especially large number of children's institutions—Young Pioneers' camps, kindergartens and nurseries—will be built there.

"Future Moscow will have one more feature, namely, it will consist of parts different in character and, consequently, differently built up and organized. The residential blocks will have schools, kindergartens, nurseries, shops and playgrounds. The industrial quarters require wider approaches, railway branch lines, etc.

"Everything I have just told you is a matter of the coming 10-15 years. And now," Yevstratov laid down his glittering pointer, "let us take a walk through one of the streets of Moscow of a more distant future—21st century Moscow.

Air of Mountain Peaks

"Do you feel how pure, as though saturated with the fragrance of meadows and groves, the air is? It is not only because of the large number of gardens and parks. A car resembling a wingless bird flashes past us noiselessly. You cannot see any exhaust gases rising behind it. The entire city transport has been electrified. This car gets its power in the form of high-frequency current from wires laid underground. Incidentally, high-frequency currents are also used in the winter time to clean the snow from the streets. They heat the roadways and sidewalks. The snow melts as soon as it falls. This installation was made possible by the abundance of electric power. Expensive? Wasteful? But do you know that in the 1950s we spent almost as much petrol on snow-cleaning in cities as we did on sowing our crops?

"Look round yourselves! There are no smoking factories or power stations. Moscow's industry hardly uses any fuel, for it gets all the power it needs in the form of electric current. Even in the kitchens of the Muscovites' homes the gas which the Muscovites liked so much in the middle of the 20th century

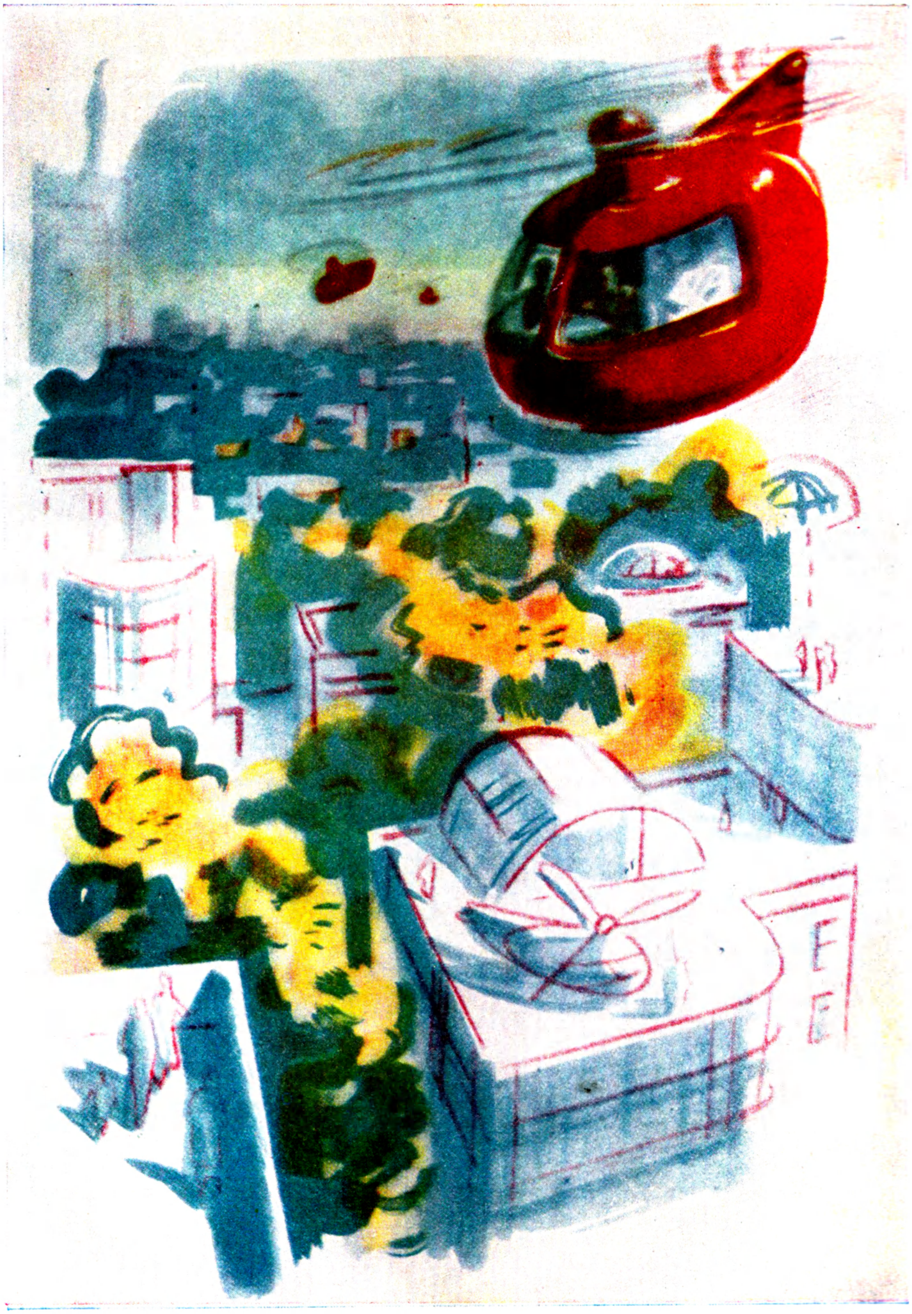
has been supplanted by electricity almost everywhere. Many industrial enterprises have long since been moved out of Moscow."

We were out on the embankment of the Moskva River. We could see every pebble on the river floor. Little shoals of silver and gold fish wound in between the weeds. The sewage was no longer drained into the Moskva River. It was purified locally and the products of purification were utilized. The purified water was oxygenated and only then drained into the river.

Night was falling and the whole street was evenly illuminated with electric lights. The daylight lamps were not suspended from wires or mounted on lamp posts. They were distributed along the fronts of the houses, forming a light panel and shedding an even light indistinguishable from daylight.

The long familiar scarlet letter "M," the sign of a Metro station, was beaming on the square. From the 74.1 kilometres in 1959 the network of underground electric railways had increased to 220 kilometres. A map of this network was hanging before the entrance to the station. The Metro lines had spread to all the districts of Greater Moscow and had joined them into a single whole. But in addition, the map showed other lines as well. These lines which ran to the centre of the capital and were not directly connected with the Metro system were railway lead-ins. They connected the Northern Railway with the Kazan and Kursk railways, the Kursk Railway with the Kiev Railway, etc. Those who came to Moscow found themselves in the centre of the city, whereas the transit passengers experienced no discomfort connected with changing for trains departing from terminals located at the other end of the city.

The fronts of the 4- and 5-storey houses rising behind the green wall of trees and shrubs were beautiful, and it is precisely of such houses that 21st century Moscow will consist. We enter one of them. A lift took us up to the top floor. We asked permission to see the very first apartment. We found light rooms with wide windows and openings through which the rooms received conditioned air. But what about radiators? There were none. The radiators had been supplanted by panels. Heat pipes had been placed in the ceilings, walls and under the floors, something that increased heat radiation severalfold, which in its turn made it possible to lower the temperature in the heating devices. Dust adheres to steam-heat radiators and spoils the air in the rooms. The water in the panel pipes has a temperature of only 40-50° C and no dust can adhere to these pipes.

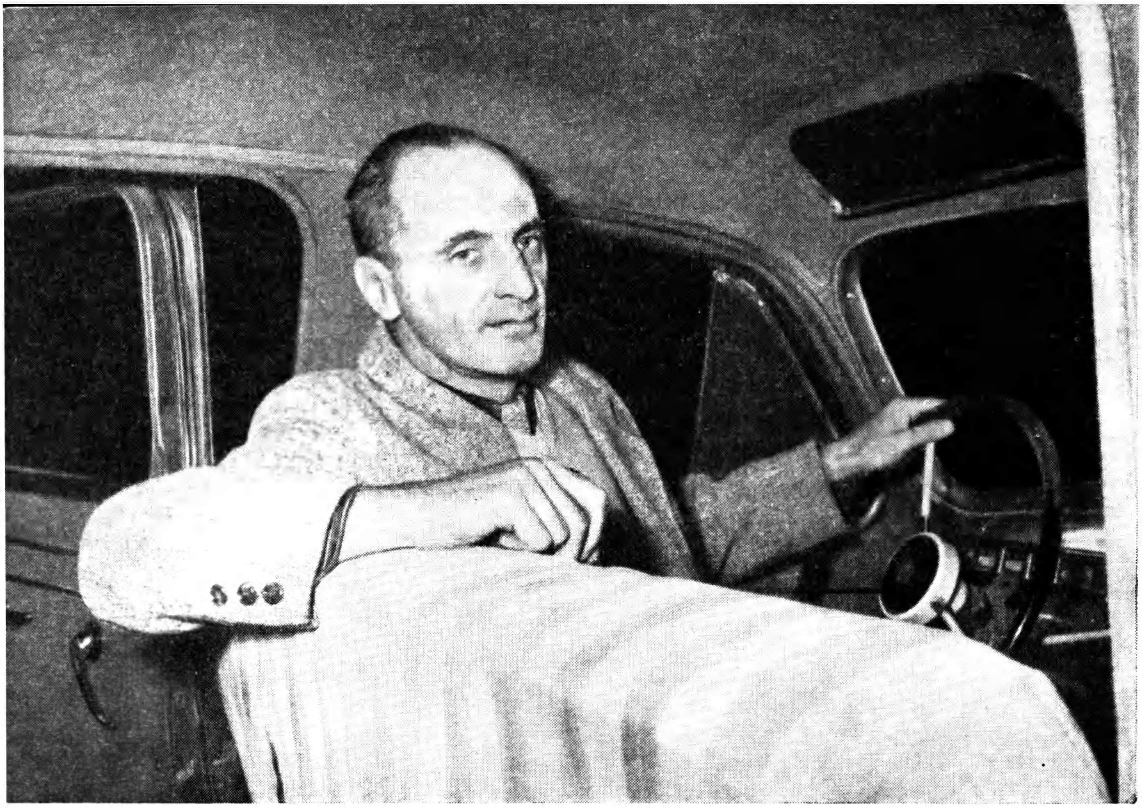


Our aerial taxi was flying over a beautiful city.

We went out on the flat roof of the house. What was this queer winged machine? By the traditional checkers on its body we guessed it was a taxi. But the 21st century taxis are helicopters. The rotor blades droned out and changed to a shiny open umbrella.

Aerial Taxis Are Not a Luxury but a Means of Conveyance

We rose over 21st century Moscow of which we were able to see only separate fragmentary features during our short excursion, and the plan we examined in Yevstratov's study, now materialized, stretched beneath us drawn by the bright lines of electric lights from horizon to horizon. We peered into the web of lines recognizing and yet failing to recognize them. And in the distance, shining in the sun, rose the majestic monument to the founder of the Soviet state—Vladimir Lenin.



Model of the Year 2010

"Are you going my way?" asked engineer Yuly Dolmatovsky. "Hop in, then, and I will give you a lift. It is a very good 2010 model car."

We approached a silvery drop-shaped car with a body hugging the ground on wheels which appeared very small compared with those we were accustomed to. Its narrowed rear end was equipped with a tail resembling that of a high-speed aircraft. The soft body lines smoothly merged into the horizontal and vertical planes of the tail which was abruptly cut off at a slant. The perfectly smooth surface of the car showed no doorknobs, bumpers or regular car windows, in a word, nothing projecting from the streamlined body of this slightly flattened drop made of strange material.

Torpedo on the Highway

"This is not metal," said the engineer pointing at the body. "It is a special material with extraordinarily interesting properties. What do you say we get in and see the inside of it?"

The engineer did not even put a finger on that amazing car, but no sooner did he utter the last words than a large aperture appeared in its side. Appeared is right, for it did not really open. It was apparently a sliding door.

We got in. From the inside its walls seemed transparent. The small instrument board with a few push buttons of the controls was in front. The seats could be arranged at will. Dolmatovsky turned his seat and sat down comfortably, his back to the front end of the car and facing us who took the rear seats. In an even voice and without so much as turning his head he said:

"Course—south-west to the turn for the city of N."

The car started and picked up speed so smoothly that we were barely aware of it. A minute later our driverless car sped down the grey ribbon of the highway at the rate of about 250 km/hr. The buildings flashing past us made our heads spin. The engineer pressed on some button and the walls of the car immediately lost their transparence, although light continued to penetrate through them and it was as light inside the car as it had been before. "Polarized glass," it occurred to us.

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"And now let us go 100 years back, to the time when the newly-appeared automobile was a sight that staggered the imagination," said the engineer.

"Can you possibly compare the slow, rattling carriages of the beginning of the 20th century, which one is tempted to call 'motor carts,' with the comfortable home on wheels they became in the middle of this century? They are very conveniently equipped with things you will not always find even in fine apartments, for they have radio receivers, adjustable lighting, heaters and cigarette lighters and are not infrequently air-conditioned. The motor, radiator, baggage compartment and streamlined voids took up 50 per cent of the volume of the cars even of the mid-20th-century models, and only 50 per cent of the space was available for the passengers.

"The 1960s were marked by endeavours to reduce the space taken up by the equipment, and today it takes up no more than 20 per cent of the total volume of our car.

"As you see, this '20 per cent' includes the means of automation; you have already noticed that the car can be driven by verbal instruction. The automatic devices drive the car by the shortest route in the assigned direction

without my intervention. This enables the passengers to read, listen to the radio, watch a telecast or talk as we are doing in our case.

"Of course, the development of such a car went on hand in hand with the development of roads for it. The radar—incidentally, it appeared in cars just about 1956—continuously contacts the highway signs. The photocells watch the light signals. The highway signs, light signals and the highway itself are all designed precisely for such cars. There is nothing strange about this, since the car has developed even the asphalted highway. The present-day highway ensures absolute traffic safety—it is always dry, it cleans and dries itself. It very largely drives the car and even supplies it with power.

"You wanted to know more about the engine in our car. You have guessed it. It is not the piston internal combustion engine of the middle of last century. The automobile piston engines were replaced by gas turbines about 40 years ago. Then the latter competed for some time with light atomic engines, while today we are riding an electric car. High-frequency current cables run under the highway. The power of the electromagnetic field created around these cables is caught by a special antenna located under the floor of the car. The cables under the highways may essentially be called the antennae of the transmitter and the engine of the car a radio receiver. The power of the high-frequency field caught by this receiver is transformed into current which drives the motors located directly in the wheels. Since the 'radiomotor' in our car is mounted on semi-conductor crystal valves, it occupies very little room.

"Now about speed. The car designers were able to design a high-speed car as far back as 1959. However, for the surface means of conveyance the practically expedient speed is but a little over 200 km/hr. This can be relatively easily explained. The resistance the automobile has to overcome adds up from the resistance to the rolling of the wheels and the resistance of the air. After about 150-200 km/hr the resistance to the rolling increases so much that it no longer pays to drive. It is more profitable to fly because it requires less power and fuel.

"This is why we use cars mainly for short trips and cover long distances by aircraft.

"You asked if we have ever designed flying automobiles. Personally I consider such machines inexpedient. To make a flying car we would have to make it more complicated and expensive, both its driving and flying qualities suffering as a result. Such a flying hybrid would be worse than a

car on the ground and inferior to a plane in the air. Flying automobiles can be used only for some special purposes.

"True, experiments with so-called soaring cars have been conducted of late. The essence of the idea is that a special device inducing Foucault currents in the ground under the car is installed under the body of the automobile. The interaction of the electromagnetic fields of these currents and the car lifts the latter 35-50 cm. in the air so that it seems to soar. There is one of these cars just passing us now. But can you call it a car? In my personal opinion, a car without wheels is no car."

Soaring Cars

Our car gently came to a stop at a glittering aluminium arch boldly rising above the highway. The car had not gone astray. The sign over the archway indicated we were at the entrance to the city we were bound for. The one-word inscription—"Welcome"—which we read beneath the sign had come to be the immortal symbol of the age-old generous Russian hospitality. We got out of the car.

"Let us leave it here," said Dolmatovsky, "for it is a taxi. We have such driverless taxis everywhere. They are absolutely safe to ride. As you saw it, the controls are completely automatic, and the car will not obey any inadmissible order."

We passed under the archway and the city came into view.

A Picture of the Future School

"And now let us see a 21st century school," said Georgy Gradov, Director of the Institute for Designing Public Buildings and Structures. "The city of N. to which you came is neither the largest nor the smallest city in our country. Nor are its schools the best or the worst in the educational system; they are ordinary, standard schools."

"Speaking about our city," Alexander Pozharsky, the Assistant Director of the Institute, joined in our conversation, "it is one of which humanity has dreamed all along its history—it is a garden city. It offers every possible convenience for work as well as recreation."

Small two-storey houses were literally buried in verdure. HF buses and HF-mobiles moved without leaving a trace of exhaust gas through green tunnels formed by the crowns of trees closing overhead. Neon lights of public buildings, libraries and clubs, also half-concealed by verdure, shone at street crossings. The buildings of industrial enterprises were separated from the residential blocks by a dense belt of greenery. No noise or dust in the air, only the fragrance of jasmine and lilac. One does not have to leave this city for a vacation, the more so since there are holiday-homes and sanatoriums right here amid these green blocks.

In one of the streets of this garden city we saw a set of two- and three-storey buildings surrounded by an ornamental fence barely visible amid the shrubs of roses and acacia. The sign on the gate read "Boarding-School 7." We went in, for it was just what we wanted to see.

A schedule of classes for the whole school hung on a wall in the foyer.

"In our days," said the principal of the school, "the material and cultural level of society is so high that we begin the education of children at the age of 5 in order to bridge the gap between the kindergarten and school. The school, too, has changed and is no longer severed from life. Today a school-leaving certificate testifies that its owner has not only received a general education but has also mastered one of the mass occupations, i.e., he is either a setter of automatic machinery, a remote-controlled mine or atomic electric station operator, an assembler of universal electronic computers, etc.

"Mass occupations of the 21st century?!" one of us exclaimed.

"Yes, and they are taught right here at school. Let us go to that building and you will see our technical classes for yourselves. Polytechnical training has long since justified itself."

The building we entered was actually a factory. No scale models or simplifications, everything was exactly as it should be in a real factory. We were unable to examine the details because our inexorable guide soon took us to the next building.

This was an athletic building. The large, light halls made almost completely of glass and resembling our present-day greenhouses were equipped for gymnastics and athletic games. There was a special hall with an ice-covered floor for ice-hockey and skating. In another hall there was a deep swimming pool in which some children were playing water polo. The park around the athletic building was also part of the athletic facilities with tennis courts, volley-ball and basket-ball grounds, cinder tracks and jumping pits. After a

cursory examination of the park our guide took us farther, past the orchard and kitchen-garden plots.

"Here the pupils conduct their biological experiments," our guide explained.

We entered the study building.

Smooth vinyl floors of pleasantly bright colours. Wonderfully light class-rooms. Walls made entirely of glass. But it was not the usual glass—it was of a cellular structure which, passing a good deal of light, excluded the sun's direct rays. A luminous ceiling shedding an even, soft, luminescent light from panels of frosted glass was turned on on cloudy days.

Each desk was occupied by only one pupil. The specially designed desks had adjustable tops and seats.

"The school physician adjusts the desks every week," said our guide. "Poorly adjusted desks may lead to all manner of postural disorders in the growing young organism."

The furniture was made of aluminium alloys, light wood and plastics. The class-rooms were almost square, something that made it possible to arrange the desks in a semi-circle, amphitheatre-like, and improved the pupils' field of vision.

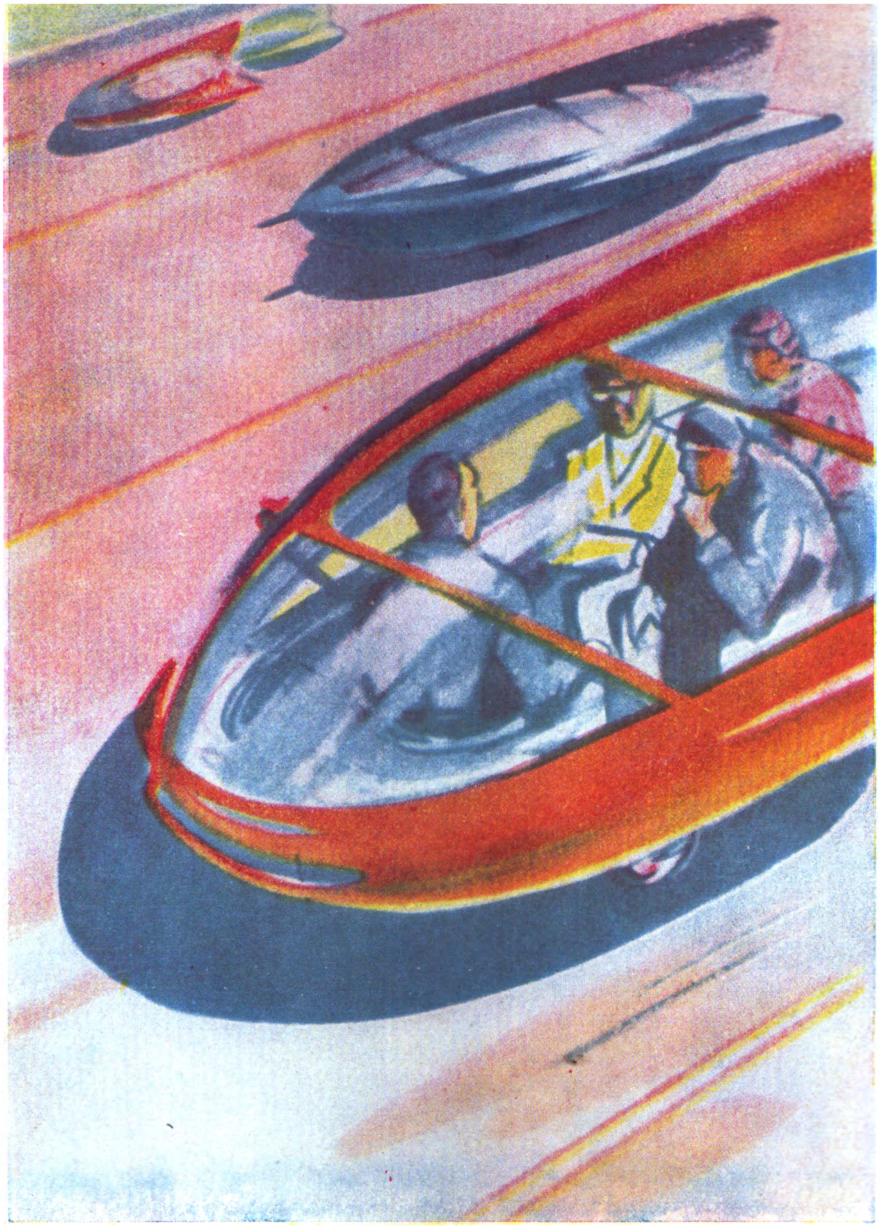
The air in the class-rooms was wonderfully pure because all the buildings were air-conditioned.

No Admittance for Bacteria

Some lamps of semi-transparent bluish glass went on at all the entrances to the school buildings the moment the doors were opened and went out as soon as we crossed the thresholds. They happened to play a very important part. Their radiations killed bacteria. Our clothes, shoes and bodies permeated by these radiations, harmless to man, were sterilized. No microbes could get into the school buildings from the street.

"Incidentally," said the principal who observed our amazement and tried to speak in a matter-of-course manner, "with the aid of these lamps we disinfect weekly all the dormitories, class-rooms and production buildings. Just to be on the safe side. But then during the eight years of my work in this school we have had only one case of catarrh and two cases of influenza. No other diseases among the 1,500 pupils have been observed.

"The sum-total of knowledge accumulated by man is continuously increasing, science and engineering are growing more and more complex and specialized; it is therefore becoming ever more difficult to master all this knowledge. Pedagogical science is thus facing the problem of developing such methods of study as might yield the best results in the shortest possible time.



The driverless car sped us towards the city of N.

Visual aid constitutes one of these methods, and films render an invaluable service to both teachers and pupils.

"Popular-science, colour sound films are shown in every class-room. Teachers use models to demonstrate complex chemical reactions or technological processes, and a coloured liquid moves, mixes and explodes in transparent vessels.

"In addition to film projectors the polytechnical shops and laboratories have TV sets. The pupils operate the machinery in their own shops and work in nearby factory shops as well. Instead of stationary posters and diagrams the teacher sometimes uses television combined with X-rays in which case a coloured picture of a working press punching an automobile body is projected on a large screen."

Boarding-schools where, by consent of the parents, children lived and received an all-round education, according to latest scientific methods, were being built all over the country. The children had a chance to ascertain their special abilities and inclinations and to start developing them at an early age. In addition to shops and laboratories, they had at their disposal an art studio, music classes, photo-laboratories, toy and play rooms, and aquariums. The parents took part in educating their children since the four-hour workday left them plenty of time for their families.

They grew up strong and healthy. It was not in vain that each school had its gymnasium, playground and swimming pool, and each class its physician who was a specialist in physical culture.

The grades now numbered 30 pupils (formerly there had been 40 pupils in each grade). Educationists believed that for best educational results the grades should be reduced to 25 or even 20 pupils.

From the class-rooms we went to the dormitories. In the rooms of the youngest children with 4-5 beds each we did not find many books, but then there were lots of toys there. They were the same dolls, animals and building-blocks as the children of our time had had, but made with much better taste. All manner of construction sets prevailed in the rooms of the children of intermediate age. Hanging over their beds we saw self-made models of aircraft, very much unlike the ones of our time, and spaceships. It seemed the dream of interplanetary travel had not lost its charm, although it had already become an everyday occurrence. The older children—they were living two in a room—had a lot of books, photographic and motion picture cameras and easels. How full the life of our young descendants—the children born on the eve of the 21st century—in the boarding-schools was!

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We went out into the street and looked at the ensemble of school buildings. Everything in these buildings was designed with a view of giving their little inhabitants a maximum of comfort, space, light and air. And how much richer than we had been were the builders of this fairy-tale school. They could certainly afford, had they wanted, to build schools with porticos, columns, towers and spires which the architects of our time had built so plentifully. The principal of the school shook hands with us and asked us to come again. Led by Gradov and Pozharsky we resumed our walk through the streets of the 21st century city.

At the turn of the street we saw the domed roof of a large motion-picture theatre with, as we learned later, a seating capacity of 2,000. Its front finished in polished aluminium, bronze and plastics shone with its garlands of neon and argon lights. Adjoining it was a large glass-roofed and glass-walled foyer which was actually a winter garden. In its cozy nooks and corners one could sit comfortably in a rocking-chair and read a book near a fountain, see a TV programme or listen to the radio. Exotic plants—palms, olives, laurels and lianas climbing special rods—pleased the eye with their eternal greenness and contributed to perfect relaxation before the film show. Here, too, we found a café, a restaurant and a city library. All in all it was a complex of institutions where you could spend three or four hours pleasantly and profitably, where you could relax and learn something interesting.

For finishing the fronts of the city buildings architects had made use of fluorescent paints so that at night the buildings gleamed amid the foliage.

At night picturesque nooks and corners in the parks came to life. Hidden coloured flood-lights illumined the trees, lawns and flower beds, while underwater search-lights lent an enchanting atmosphere to the reservoirs. Groves of fountains sprang up in the parks and played against the background of crimson flowers during the day. How wonderful it was to walk through such "thickets" on a hot summer day!

Architect Gradov told us how the problem of heating was being solved in this city. It appeared that radiators made of semi-conductor elements were placed under the floors and in the walls of the buildings. These elements possessed a remarkable property, namely, they heated if current was passed through them in one direction and cooled if it was passed in the opposite direction. They went on automatically and acted one way or the other depending on the temperature of the air inside the buildings.

"This winter garden presents a beautiful sight when it is 30° C below," said the scientist. "The snow runs down the transparent walls of the greenhouse—they are made of three-layered glass blocks from which the air has been pumped out—while magnolias are in flower inside. Incidentally, one more interesting detail in the life of the inhabitants of this city. They do not have any winter clothes, i.e., not in our conception (fur coats, fur caps, felt boots). As a matter of fact, they hardly need them. They have special clothes for outdoor work and sports, but for running out of an air-conditioned home and getting into an air-conditioned car fur coats are of no use.

"The speed and low cost at which the new housing is developed, as well as the super-speed transport (electric trains travelling at the rate of 200 km/hr, and helicopter taxis) have made it possible to build towns and residential districts in any picturesque spots, away from the large cities and the 'old' industries. Chains of satellite towns have made their appearance. Residential and public buildings, whole streets for that matter, are worked into the colourful natural landscape and are adjusted to it. Architects have more than ever before become artists."

Humanity had vast power resources and therefore no longer economized on fuel to heat the houses. The homes had wide windows, glass walls, loggias and balconies protected with glass covers from rain and snow. Owing to such construction the exterior of these buildings appeared colourfully plastic. The light walls were painted in harmonious colours. Thanks to the different façades, colours and heights of the houses, the overall effect was that of thousands of inimitable architectural compositions despite the building standardization.

The combines, which simultaneously dug ditches, laid fibrous-glass pipes and collectors in the ditches and then filled these ditches in, expedited the development of the residential districts, i.e., the building of water-supply, sewerage and heating systems, etc.

Town-building was now making extensive use of plastics. The buildings were made of strong glass plastic with oriented threads, of new metal alloys, and of light, thin but strong plastic curtain walls with effective thermoinsulation. The new structures were 5-10 times as light as the old brick buildings. Large and completely finished building units were being produced in batches by automatic plants. One of these plants alone produced as many residential buildings a year as dozens of plants and construction sites had turned out in all of Moscow in 1957.

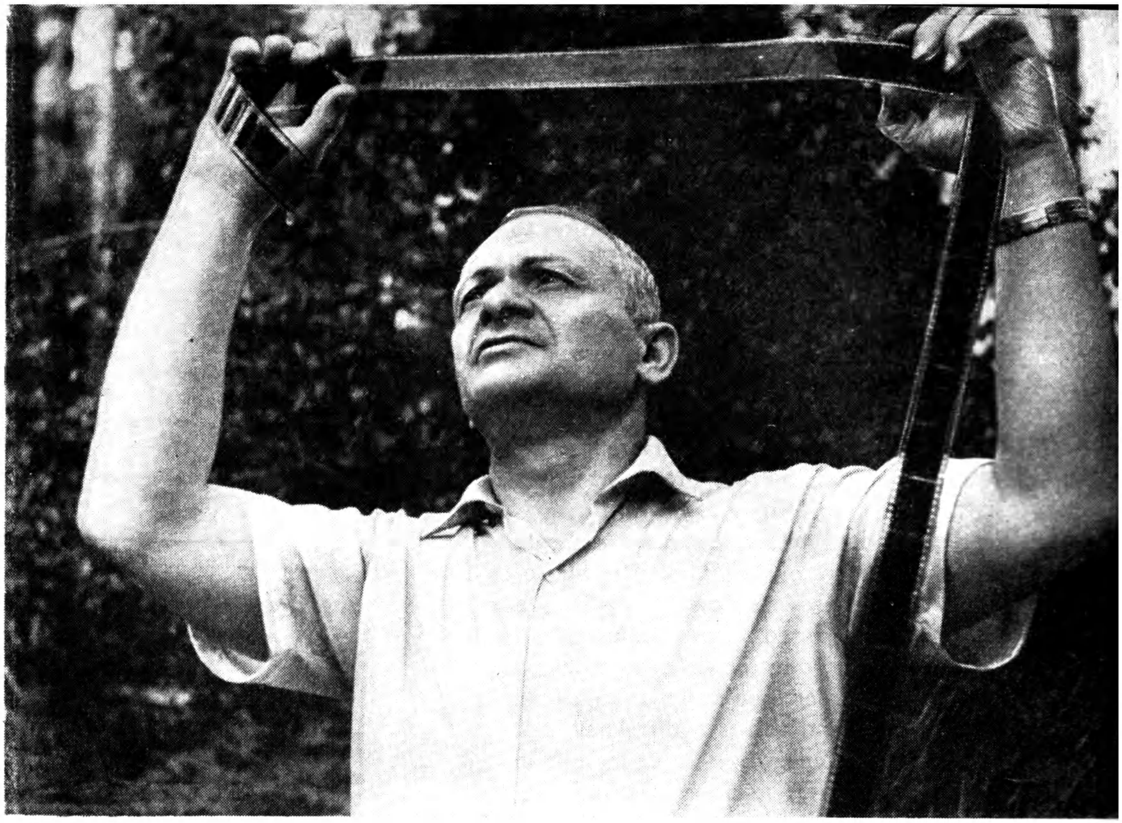
There Were No Sick, What Were the Hospitals to Do?

Now that the housing shortage had been done away with and numerous comfortable hotels had been built, the salutary effect on the nervous system and health of all the working people in general had at once become apparent. By force of habit some people continued to go to the country every spring; they loaded portable plastic houses on helicopters or lorries and went to the mountains or sea-shores, wherever they liked it best. It took them but a couple of hours to put up their 3- or 4-room villas with their own hands, without the aid of builders or cranes.

Others preferred to have company during their holidays and moved to drifting islands, peculiar health-resort towns accommodating between 3,000 and 5,000 people. These islands drifted slowly along sea-shores and visited picturesque bays.

On the drifting islands, as on land, there were changeable theatre buildings which could be quickly transformed into circuses or wide-screen cinemas.

"Incidentally," said architect Gradov, "although this is a different subject, I regret that I did not show you a single film in the motion-picture theatre of the future. If I tell you about the wonders of cinematography I wager there is a good deal you may not believe. I think Professor Y. Goldovsky could tell you most and best about it. Pay him a visit. He is a well-known specialist in the field of cinema techniques."



Magnetic Photographs and Films

"Come into the cinema of the future," Yevsei Goldovsky invited us. "Only we shall not go through the foyer which you have already seen but through this inconspicuous door leading to the projection box.

"You see several apparatus here. They are very much unlike each other. They even operate on quite different principles.

Three Brothers Unlike Each Other

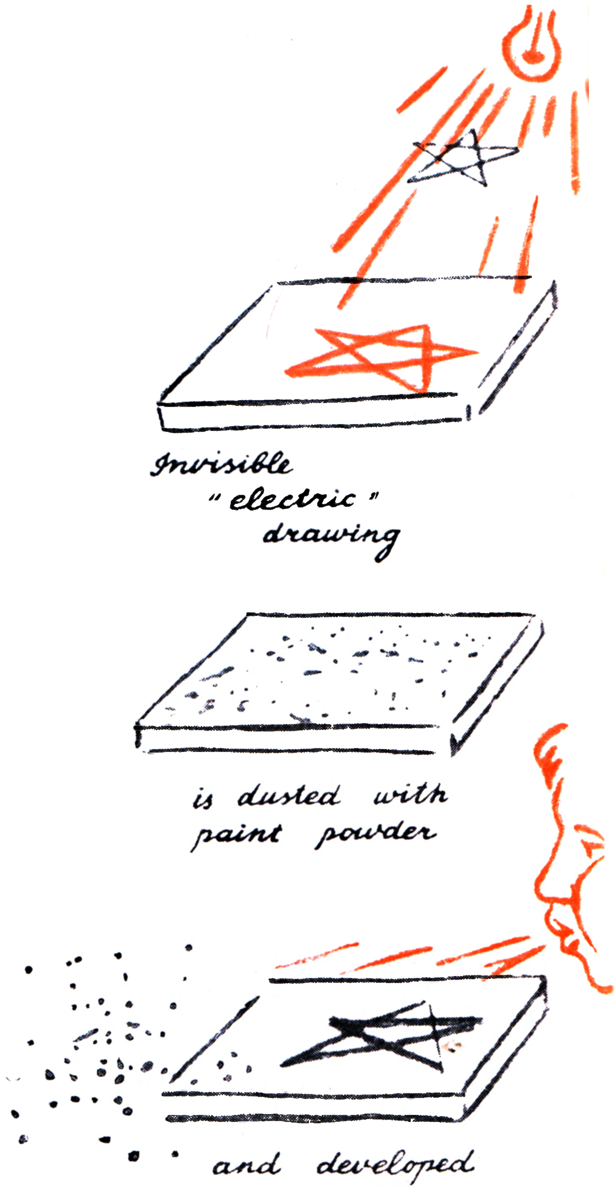
"The one on the extreme left is in fact a specially designed TV-receiver. It is used for demonstrating on the vast screen athletic meets, parades, meetings and other events which cannot be attended by all who would like to attend them. Films of which no copies are available can be demonstrated with the aid of this TV-film projector.

"The image arises in it on a small screen of the cathode-ray tube whence it is projected on to the cinema screen. The first samples of analogous equipment existed as early as the middle of the 20th century.

"The projectors in the centre and on the right serve to demonstrate regular films. Here is a roll of film for the projector in the centre. With the aid of a magnifying glass you can see separate frames on this film. The film of the projector on the right is a greyish-red tape and is not transparent at all. It looks like a recorder tape rather than a film.

"And this is really what it is. The image is recorded on it in the same manner as sound used to be recorded on the recorder tape before.

"The principle of such recording is quite simple. The image is resolved into an enormous number of individual elements (points) as is the case in telecasting. Following this the signal from each point does not go into the ether but is recorded on the tape. In the projector—here it is before you—the signals are deciphered and in the form of light points are built up into an image on the screen again. The method of tape recording images is used as extensively in the



21st century as sound recording was used in the middle of the 20th century.

"But let us go back to the projector in the centre.

"The first surprising thing on the film of this projector is the absence of the infallible perforations that serve to stabilize the position of the frame before the lens. Of course, such stabilization is indispensable.

"In this apparatus a magnetic stabilization is effected by means of the magnetic points imposed on the edge of the film. Such stabilization is more precise than mechanical stabilization."

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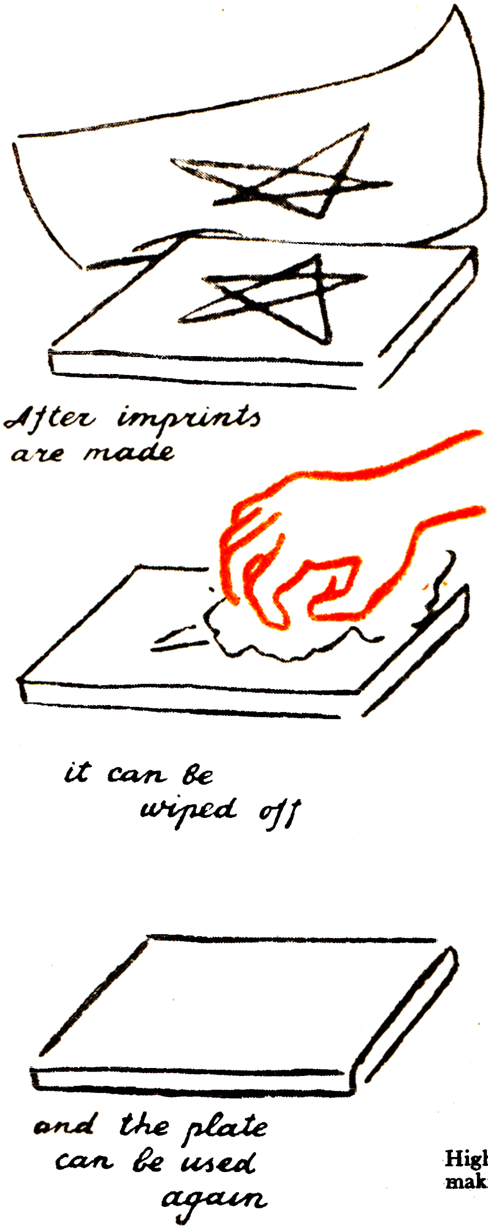
We came back from the 21st century. The professor's story grew precise and abounded in figures and technical terminology.

"Photography was invented, as is well known, in 1839. At that time to have one's picture made, one had to sit for a good half hour motionlessly, in the same pose and with the same expression on one's face. By the 1950s the time necessary to take one picture was reduced to approximately 0.00000002 of what was required formerly. Now we can take a picture in 0.025 sec. This interval of time is impercep-



High-speed, completely automated book-making machines will be able to work on this principle.

tible to the human senses. The main factor making such reduction in the exposure time possible is the increased film sensitivity. The latter has increased about 200,000-fold.

"However, this sensitivity is still insufficient. Those who have ever been to film studios know how hard it is for the actors to play before clusters of powerful lamps, flooded with merciless streams of light and heat. The efforts to increase the sensitivity of films will therefore undoubtedly be continued. The 21st century cameramen and photographers will no longer have to worry about choosing lighting; they will do without flood-lights and flash lamps. The films will be shot in ordinary light and, if need be, in twilight.

"The photographer who takes a picture today is tied up by the exposure. He must 'hit the nail on the head'; he must allow neither overexposure nor underexposure. This is due to the fact that sensitive layers have, as they say, a small latitude, i.e., they cannot stand excessive exposure or considerable reduction in lighting.

"It is to be supposed that photographic materials will be found with which the photographer will scarcely have to worry about exposure; he will be certain of producing high-quality photographs under any conditions.

Like That Anybody Will Be Able to Take Pictures

"The thing that gives the photographer serious trouble today is the large granularity of the emulsion layer. You must have seen greatly enlarged prints taken by a 16-mm. film cinecamera. In these pictures you can clearly see the individual grains—the spots which make up the image. These spots slur over the details and the clear lines. The large granularity of the film limits the possibilities of enlarging the prints. And it is the granularity that determines the size of both the photographs and motion-picture film.

"There can be no doubt that the granularity will diminish with each passing year and this will make it possible to reduce the size of the film.

"With a reduction in the size of the film the cameras will also become correspondingly smaller. I think that in the 21st century cameras about the size of our present-day Pobeda wrist watch will be in extensive use. Automatic photo-electric meters will in all probability set the necessary aperture and shutter speed.

"The present-day developing and printing of pictures is a troublesome and rather unpleasant affair, especially if a coloured print has to be made.

The photographers of the future will not have to bother with numerous solutions or worry about the necessity of maintaining a certain temperature and developing time. They will no longer use the three-layer colour film in which each layer is sensitive only to one colour, but a one-layer film which will have minute grains of all the three present-day layers.

"Will the process of photography undergo any fundamental changes? Yes, it is quite possible that present-day chemical photography will be supplanted by electrophotography. Today it is only coming into being and is about at the same stage as chemical photography was many years ago. But there can be no doubt that it has a brilliant future.

"The technique of electrophotography, or dry photography as it is also called, constitutes one of the uses of semi-conductors which will be extensively employed in the 21st century engineering and everyday life. It consists in the following:

"A metal plate is coated with selenium. Such a two-layer plate has an interesting property, namely, if the layer of selenium is given a positive charge and then lighted, the charge will, under the action of the light, go into the metal. Then the plate is put into a camera and the image is projected on it. At the spots on the plate where the light falls the charges go into the plate; wherever there is no light they remain. The result is a kind of electrical image in the form of charges distributed according to the intensity of the lighting at any particular place.

"This plate is then covered with a fine, negatively charged paint powder, paper is applied to the plate and a print is obtained. In this process sensitivity already approximates that of ordinary photography. There is special paper for it. Fifty years from now there will undoubtedly be electrophotographic films and cameras.

There Will Be No Need for "Witchcraft" with Chemicals

"Electrophotography has a number of merits. The same material, the selfsame plate can be used many times. Pictures can be made very fast—and by a perfectly dry process. Another merit of this method is the fact that, unlike the other methods, it makes it possible to protect the film from the penetrating radio-active radiation.

"I think electrophotography will also find application in motion pictures. Electric cinecameras will probably be developed.

"I shall conclude our conversation about motion picture and photo-

graphic materials by touching upon the changes that will take place in the very base of the film—the flexible ribbon which is coated with the emulsion.

"As it is today, it has a number of shortcomings—it easily tears, shortens when drying, etc. Future photographers will, no doubt, get a non-warping film, much stronger and, hence, much thinner. This will make it possible to have not only a narrower but also a thinner film so that a single reel will suffice for a full length film and a single roll of film in the camera will be enough for hundreds of frames."

Siberia Through a Stratoplane Window

Siberia! Very few people know this wonderful country. Nor is it possible for any one person to picture it to himself as a whole with all its incalculable resources and the inexhaustible variety of its nature.

Of all the natural resources of the Soviet Union Siberia has:

90 per cent of the water power,
80 per cent of the coal,
60 per cent of the iron ore,
90 per cent of the non-ferrous metals,

70 per cent of the timber,

80 per cent of the arable land.

Siberia has literally everything necessary for the development of a powerful industry. What it does not have now it soon will; it merely has not been found yet.

The Country That Has Everything

Take, for example, oil. No oil deposits are known in Siberia as yet. But large accumulations of natural fuel—oil gas—were found there very recently, which signifies that oil, too, will be discovered. And not any casual, insignificant disseminations, but large industrial deposits. By the year 2010 the prospected oil resources in Siberia will constitute a considerable part of all the oil resources in the Soviet Union.

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We were talking to Leonid Pustovalov, Corresponding Member of the U.S.S.R. Academy of Sciences and Vice-Chairman of the Council for the Study of the Productive Forces.

"You want to get a general picture of Siberia in the year 2010?! Well then, let us imagine it is 2010, take a 2010 model super-speed, atom-powered plane and fly over some of the areas of the southern half of Siberia.

"Here, in the vast Siberian spaces, near the white dams of the power stations spanning the great Siberian rivers, around some of the largest deposits of iron and non-ferrous metals, in the immense Siberian coal basins and near the boundless forests as yet barely touched by man, we shall undoubtedly have by that time large cities and numerous settlements. Siberia will be covered with a network of new higher schools of world renown, the Siberian Academy of Sciences will take firm root and develop, large new factories will be equipped according to the latest standards of the 21st century engineering, and, of course, there will spring up new and well-appointed health resorts with sanatoriums and holiday homes.

"The climate of southern Siberia—cold in winter and hot in summer—is dry and healthful and quite fit for agriculture."

We were flying over this beautiful and wonderful country in a super-speed plane. Underneath us cities, settlements, railways and highways connecting the highly developed industrial areas of Siberia came into view and disappeared behind distant horizons, and reservoirs of power stations competing in size with seas shone in the sun. From the window of our plane we could not catch all the details but some of the most important features of Siberia of the beginning of the 21st century showed quite clearly.

Below was Krasnoyarsk Territory. Our plane was flying a due east course. It crossed a cascade of power stations located on the Angara River which issues from the gigantic bowl of Lake Baikal. Siberian cities, none of which had been on the map even in the middle of the 20th century, new plants and settlements stretched in an almost continuous chain on the shores of the reservoirs which sprang up along the Angara but recently precipitate, deep and full of rapids. Industries requiring a lot of cheap electric power were predominantly concentrated here. These were aluminium and magnesium plants, electrometallurgical enterprises, chemical fertilizer plants, etc. It was one of the country's largest industrial centres.

Heat and Power Plants Compete with Hydro-electric Power Plants in Economy

This centre owed its existence not only to the cheap hydro-electric power but also to the extensive utilization of the coal of one of the world's largest coal basins—the Tunguska Coal Basin.

Flying over Krasnoyarsk Territory we recalled the heated discussions that raged among the Soviet specialists in the middle of the 20th century, some of them maintaining that the industry of the Territory should be developed on the basis of the hydro-power resources, the others contending that the industrial development should be based on the inexhaustible local mineral fuel resources. The advocates of the latter point of view admitted that the electric power produced by the hydro-electric power plants was much cheaper than that produced by the thermal electric stations but argued that this general rule was not applicable to Krasnoyarsk Territory where thermal electric power could be produced as cheaply as that of even such perfect hydro-electric power plants as the Stalingrad and Lenin Volga plants. This is due to the fact that in Krasnoyarsk Territory the coal beds came out directly to the surface or were covered with a thin layer of sediments. The coal could be easily mined with an excavator and loaded with a minimum of expense on a transporter that ran directly to the boiler room of the heat and power plant.

Yes, Siberia is a country of wonders, and the so-called general standards cannot be applied to it. "It needs its own yardstick," the specialists in the middle of the 20th century said in propounding the idea of developing Krasnoyarsk industry mainly on the basis of the very cheap local thermal power.

But the picture appearing before us beneath the silvery wings of our atomic bird showed that life had taken neither of the two extreme courses. The controversy which in its time agitated the minds of specialists

was finally expediently settled by a rational combination of hydro-electric power and thermal electric power. From our plane above we saw that, in addition to the large hydro-electric power plants which had came into being towards the beginning of the 21st century, Krasnoyarsk Territory was covered with a ramified network of heat and power plants supplying power to the nearby industrial enterprises. This cut the costs since it obviated the necessity of transmitting electric power over long distances.

Our plane veered somewhat to the north and we flew over the territory of Yakutia. Underneath was the basin of the Vilyui River. Fifty years ago

From up in the plane we could discern

this area had been covered with a dense and impenetrable taiga; now it was the centre of the Soviet diamond industry. Here there were spacious buildings of concentrating mills and populous settlements with straight-as-an-arrow streets and avenues. The diamond workings were concentrated in the famous Siberian "eruption pipes" filled with peculiar diamond-bearing rock—kimberlite. On the surface the pipes have an almost true cylindrical shape; they run deeply and almost strictly vertically into the interior of the earth.

only the general features of industrial Siberia.

We recalled the long and complicated history of the discovery of the Soviet industrial diamond deposits. The first single diamonds were found in the Urals as far back as 1829. They were unsuccessfully prospected for by Alexander Humboldt, well-known German naturalist, and his associate Gustav Rose who, in the first half of the 19th century, made a long journey through the Central Urals and Altai to the Chinese border. The tsarist government repeatedly financed the prospecting for Russian diamonds but the prospecting of the time was primitive and incapable of producing the desired results. Systematic and extensive prospecting on a truly Soviet scale was organized only in Soviet time. Vast regions of the country were systematically explored in the search for diamonds. It was a long time though before the geologists could lay their hands on diamonds. The first diamond pipe was finally found in the basin of the Vilyui River only in the 1950s. The Soviet geologists named it the "pipe of peace." After this, diamond pipes were discovered one after another. Now, in the beginning of the 21st century, a vast diamond-bearing area stretching well beyond Yakutia was discovered in Siberia.

Diamond Pipes

It had been a long time since the owners of the South African diamond mines dictated their monopoly prices in the world diamond market. The Siberian diamond deposits successfully competed with the South African mines both in quality and quantity of the mineral mined.

We turned on the radar and saw in the vicinity of the Vilyui River these cylindrical hollows that looked, to us up above, like dents in the earth's surface. Each of these dents was an opencast working of a diamond pipe. It was from here that the Soviet industry was supplied with the precious raw material for the manufacture of diamond cutters used in machining super-hard metal, of diamond drills required for drilling especially hard rock, and of particularly important friction parts of precision apparatus and instruments. From here, too, Soviet diamonds went for export.

Our plane kept on its due east course. We crossed the sparkling ribbon of the majestic Lena River flowing along the wild Verkhoyansk Range. From our great altitude we barely discerned some dots which were actually oil derricks. It was the new Yakut oil-bearing area in Siberia, named the Third Baku. Nearly 50 years earlier the Yakut geologists had discovered the first large oil gas deposit here. This justified extensive prospecting for oil. Now, in the beginning of the 21st century, Siberia was supplied mainly by the Yakut Third Baku. From here oil and gas lines ran in every direction supplying the Siberian cities, plants and mines with liquid black gold.

Now we no longer saw tank cars on the Great Siberian Railway transporting oil from the western parts of the U.S.S.R. to the eastern areas.

Our plane made a sharp turn south. Before long we found ourselves flying over Yakutsk, the Yakutian capital, and about half an hour later over the Aldan mining area. At one time it was known only as a gold-producing region, but it had changed since then. From up above we saw numerous coal mines dispersed over the territory of the South-Yakut coal basin, one of the largest in the Soviet Union.

This basin is also one of Siberia's wonders. In the other coal basins the most valuable sorts of coking coal constitute the smaller part of the basins' resources, but here, in the South-Yakut coal basin, discovered and prospected by Soviet geologists in the middle of the 20th century, coking coal constitutes the greater part of the coal.

The vast deposits of the South-Yakut metallurgical coal are adjoined by the large deposits of high-grade Aldan iron ores. It is very rare for iron ore and coking coal, the two most important metallurgical raw materials, to be found nearly side by side and thus to require very little expense to be delivered to the works.

Flying over the Aldan mining region we therefore saw not only the coal and iron ore mines but also the new iron and steel works, something that had made it unnecessary to transport pig iron from the remote areas of the Soviet Union to the eastern regions of Siberia.

We recalled that very recently, June 11, 2010, the newspapers published the agreement on communist emulation between the workers of the Aldan and Nerchinsk iron and steel works, the latter had been put into operation but a short time before.

The Nerchinsk Iron and Steel Works was somewhat off our route in Chita Region; it had been built on the site of the former Nerchinsk tsarist hard labour camps. Now it is a prosperous country with a highly developed industry of ferrous and non-ferrous metals. The metallurgical coal was brought here from the South-Yakut Coal Basin by a newly built electric railway. This was one of the numerous forms of economic relations between the different Siberian economic areas.

After crossing the Stanovoi Range our plane approached the sparkling ribbon of the Amur River.

Only a little over 25 years ago the catastrophic floods of the Amur and its Soviet and Chinese tributaries—Zeya, Bureya, Selemja, Sungari, etc.—had systematically caused the Soviet and Chinese peoples damages running

into many millions of rubles. It had been a basin of rivers with tremendous but unbridled power.

Since then the Amur and its main tributaries had changed radically. Blocked by a series of dams the turbulent rivers submitted to the will of man and now flowed quietly. The land reclamation measures carried out since then increased the areas of fertile arable land. The Amur basin no longer suffered from floods. Large power plants supplying the new Soviet and Chinese industrial enterprises with cheap power had come into being. From our high altitude we could barely distinguish the high-voltage transmission lines which poured the electric power of the Amur power plants into the single Soviet power grid.

Four Mouths of the Great River

Development of the Amur considerably enhanced the transport importance of this great river. The Sungari River, Amur's right tributary, was now connected by a canal with the Liaohe River. Through the Sungari-Canal-Liaohe system Amur ships with passengers and cargoes could sail from the Amur directly into the non-freezing Yellow Sea and thence to any Chinese port. Besides, through the Ussuri and Lake Hanka the Amur was now also connected with the non-freezing Gulf of Peter the Great near the city of Vladivostok. Lastly, somewhat south of its former natural mouth, the Amur was connected with a more southerly, and hence more convenient for navigation, part of the Tatar Strait. Thus, in addition to its former mouth, the water-abounding "Father" Amur now received three new outlets to the open sea and was transformed into an important international transport artery.

The time when the Amur as a border river divided the Soviet Union from China was long since gone and forgotten. Now the river, on the contrary, united the two powerful socialist countries—the Soviet Union and the Chinese People's Republic.

Formerly the Chinese had called the Amur "Heilungkiang" which means "the river of the black dragon"; now they called it "the river of the electrical dragon."

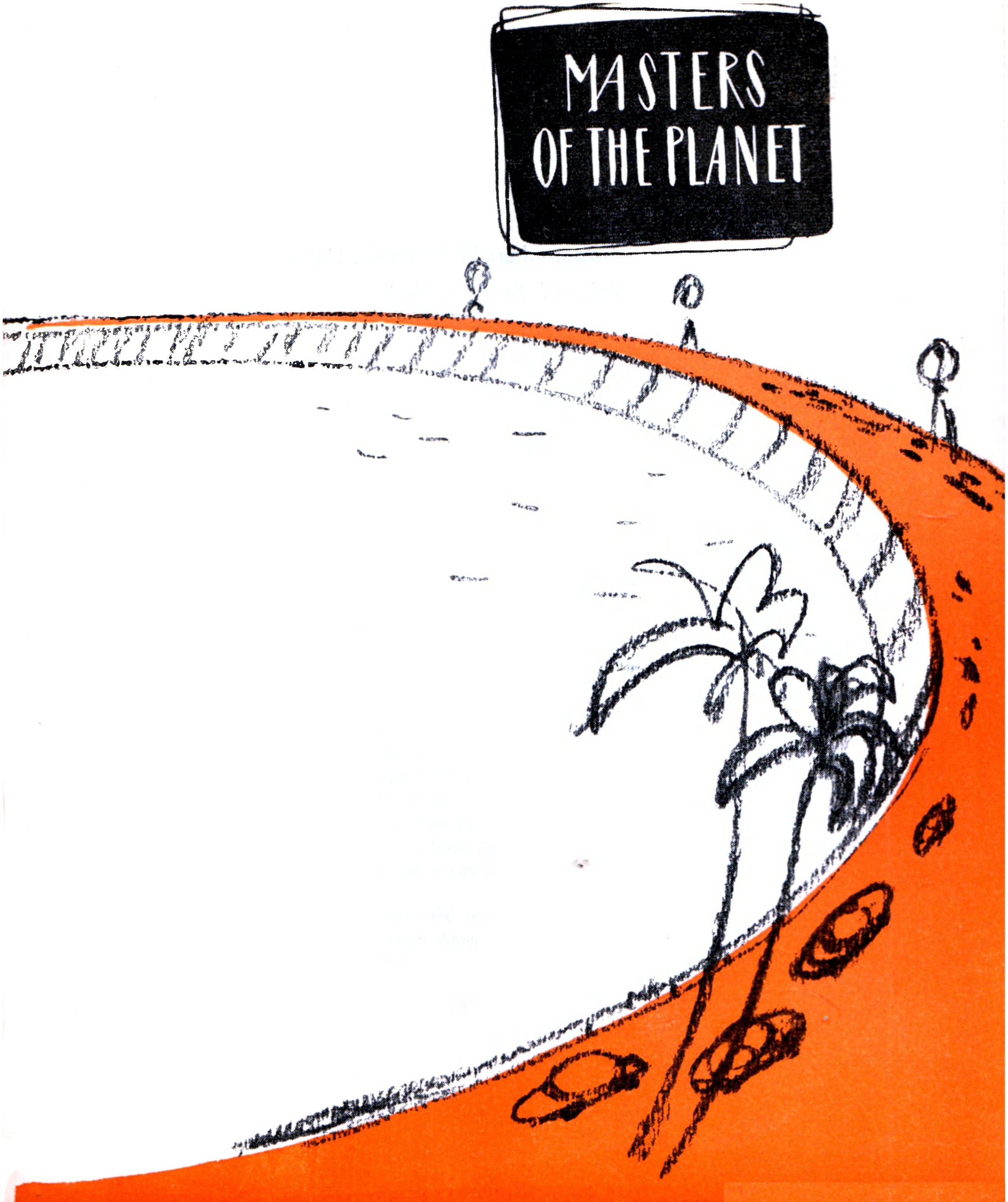
A little change in the course of our flight again and we were flying north over the Sea of Okhotsk. And here was Kamchatka, the country of active volcanoes and geysers, the last point of our imaginary journey.

Fishing was still the leading industry of the Kamchatka Economic Area, but the fishing techniques and the equipment of the canneries had been considerably improved. In addition to the highly developed fishing industry, mining of combustible minerals had considerably expanded and a new and

multiform mining industry had come into being during the last decades of the 20th century. Such rare and dispersed elements as mercury, arsenic and antimony had been discovered and were being vigorously mined. In origin they were closely connected with the magmatic activity of which we were reminded by the Kamchatka volcanoes and geysers. From the window of the landing plane we could clearly see the Kamchatka volcanoes with smoking peaks. The volcanoes continued to smoke as they had in the 20th century. This was an echo of the underground activity of the hot molten magma, here located quite close to the surface.

The Kamchatka hot springs are also connected with the molten magma which is cooling in the interior of the earth. Their free thermal energy was extensively utilized for industrial and everyday needs. The Kamchatka Economic Area depended for most of its power on the free underground heat. The volcanic activity which constituted a specific feature of Kamchatka and the nearby islands had but very recently caused man a lot of trouble. Now the same volcanic activity placed at the service of man gave the inhabitants of Kamchâtka the cheapest power in the U.S.S.R.

But our plane had already landed and we had to get out.


MASTERS
OF THE PLANET

Geographers Will Remake Nature

Pulse of the Tatar Strait

According to the Bible, it took God only six days to create our earth with all it contains inside and on the surface and even with all that surrounds it, including the sun, moon and innumerable stars which are much larger and often probably more complex than our earth, the tiny speck in the infinite universe. It is hard to say how things are on the numerous planets revolving around the other stars, since we have no adequate knowledge of either the conditions that prevail on them or of whether or not their living and thinking inhabitants are satisfied with their planets, but as far as the earth is concerned any engineer will tell you that our planet could certainly have been designed much better.

The construction of the earth can be criticised from various points of view. For example, the minerals are not very handily distributed. There are countries and even whole continents that lack some vitally important minerals. Nor are the minerals very happily grouped for the purpose of their complex utilization. For instance, it would be desirable to have iron ore deposits next to beds of coking coal, aluminium ores in the vicinity of cheap power sources, and deposits of Chile saltpetre, one of the most important fertilizers, in the principal agricultural areas. But, alas!—as a rule, this does not happen to be the case.

In the future, too, man will probably have to adjust himself as best he can to this poorly designed planet, as tenants have to adjust themselves to a flat that is not designed exactly to their taste.

Whenever the tenants intend to stay long in a flat they make the necessary changes and fit it to their hearts' desire.

People similarly have to reshape their common home—the earth—according to their tastes and requirements. Of course, they cannot change everything, nor can we, for that matter, alter everything even in a ready-made house.

Vast irrigation systems which transform large areas of arid lands into flowering gardens and fields have existed in many countries since antiquity. Is this not reshaping nature?

Thin threads of canals have connected seas and oceans and have separated continents—Africa from Eurasia and South America from North America. Does not man thus remake the map of his planet?

Nature has been remade on a particularly large scale in the Soviet Union. The narrow ribbon of the Volga has been transformed into a continuous chain of big lakes. New sea-like reservoirs have come into being on the Dnieper, Don, Yenisei, Ob, Kama and other rivers. Irrigation canals penetrate ever deeper into the arid zones. Forest belts are rising to block the way to dry winds. All this is changing the map of the U.S.S.R., its climate, the animal and vegetable kingdoms, in a word, all that is customarily referred to as nature.

But these are only the first steps, the first timid attempts to change nature. In the future, as man extends his powers he will reshape nature on an even greater scale. And perhaps then a complete list of the structural defects of the earth will be drawn up, even as an experts' panel draws up a list of defects of some particular machine. Some of the entries in this long list we can already imagine today.

The land making the existence of man possible occupies less than 30 per cent of the surface of our planet. This is a radical defect and one that is hard to eliminate, although a more advantageous ratio between the land areas and ocean, from the point of view of man's convenience, could be achieved.

For some reason or other the land is accumulated in large blocks mainly in one hemisphere. If the problem of a complete reconstruction of the planet ever arises, it will probably be necessary to think about a more even alternation of sections of land and ocean. A continuous alternation of strips of land and ocean, something like a net covering the earth, appears to be the most expedient, the strips of land corresponding to the ropes of the net and the reservoirs to its cells. But such replanning is also an extraordinarily complicated affair.

Deserts cover a fairly large part—almost 15 per cent—of the land surface. This is enormously wasteful and should not be tolerated.

An offensive is being waged against the deserts, and the day will come when school children go on excursions to a reserve where a few thousand hectares of the last desert on earth will be fenced off as a relic, a memorial of the remote past.

And what about the distribution of heat and cold on the earth? Some areas languish with oppressive heat all year round, in others the temperature never rises above zero. A continuous glacier always covers 16.3 million square kilometres of land—a whole continent and numerous islands. Monstrous injustice! Our descendants will have a hard job redistributing the thermal income of the earth more evenly over its surface.

And the mountains? Inconvenient and frequently unfit for human habitation. See what vast areas are coloured a dark-brown on the physical map. No, not even the most mediocre engineer would have placed so many stiffening ribs—mountain ranges—over the surface of the earth if he were designing our planet for living.

We could go on criticising the construction of our planet but we feel that it is perhaps somewhat premature, especially since man can still do very little to reshape the earth. He has barely finished studying its geography and is as yet far from having complete knowledge of its geology.

However, man could already plan and even effect some world-wide changes on our planet.

The Soviet project of building a powerful dam in the Bering Strait is known far and wide. It is also common knowledge that a cold current runs through this Strait from the Arctic Ocean into the Pacific. The leaden grey waves of this current carry icebergs, fog and cold. The current enormously affects the climate and weather of the whole Primorye territory. The dam could block this current. Even present-day engineering would have no particular difficulties in building this dam since the Bering Strait is only 85 kilometres wide and on the average about 40 metres deep.

But this dam is only half the job. Scientists believe it advisable to make the dam not only a passive obstruction to the cold current but also an active creator of a new, warm current flowing into the Arctic Ocean. For this purpose it is necessary to install in the body of the dam hundreds of large propeller pumps powered by atomic electric stations built on the shores of the Strait. These pumps will be able to move from the Pacific to the Arctic Ocean 100,000 cubic kilometres of water a year, i.e., to create a second, Pacific, Gulf Stream. This current will carry from the tropical zone of our planet to its arctic regions two or three times as much heat as is contained in all of the world oil resources.

This will change the climate of Kamchatka, the north-eastern part of Siberia and Alaska, and the thermoclime of the Sea of Okhotsk and several seas of the Arctic Ocean. The important thing is that this will make a vast area warmer.

There are also other similarly grand projects which can be carried into life with our present-day productive forces. A dam can be built to run along the Newfoundland shoal and throw far into the Atlantic Ocean the cold Labrador current which now freezes a large section of the east coast of the U.S.A.

By damming the Strait of Gibraltar it is possible to take away from the Mediterranean vast areas of very fertile land which now constitute its floor.

The warm Kuroshio can be turned to the cold Sea of Okhotsk.

Large fresh-water seas which will make the climate of the whole African continent milder can be created in the wastes of the Sahara.

The great Siberian rivers can be turned south in order to irrigate the deserts of Central Asia.

Engineers have found, thought out and calculated many more great "can's."

What do we need to carry these great projects into life?

In the very first place we most probably need peace, friendship and understanding among all the peoples for whom our world is the common home.

In this chapter we let the scientists who are dealing with these problems tell their stories.

Geographers Will Remake Nature

"So you believe that by their very nature geography and geology are sciences that cannot develop infinitely because the object of their studies—our planet—is limited? Yes, you are right, to some extent. But at the same time I can wager that geography and geology are facing most extensive prospects for development not only during the 21st century but also during the coming hundreds of years."

We were seated in the modest but very comfortable and even cozy study of Academician Dmitry Shcherbakov in the building of the Presidium of the U.S.S.R. Academy of Sciences. On the wall there was a geological map

of the U.S.S.R. Near the desk set we saw a large—by the looks of it weighing about two kilograms—fragment of dark-green rock pressing down a big stack of foreign journals in brightly coloured covers.

His eyes slightly screwed up, the host looked at us with a smile. He had seen a lot, this grey-headed and very tactful person. The northern lights had flickered over his head, the arctic ice of the drifting stations had crackled under his feet, and the winds of Tibet had blown in his face. Very recently he had visited Indo-China. Yet he was past sixty. During his lifetime he had travelled through the Khibiny Mountains, the Central Asian deserts, Kamchatka and the Carpathians. He had visited many countries and cities, his itineraries covering the whole world. He could see the prospects for the development of geography and geology more clearly than anyone else.

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"We often say that there are hardly any more 'blank spots' on the map, i.e., places unknown to man. This is not quite true, because in Africa and South America, to say nothing of the Antarctic, there are still vast unexplored areas.

The World Is Full of Secrets

"Very recently, in 1954, Australian planes discovered in New Guinea areas inhabited by tribes which carry on no intercourse with the coastal areas. According to approximate estimates, they number about 100,000. Not a single ethnographer has as yet visited their village huts, nor has a single linguist studied the roots of their language. And was not the discovery of diamond deposits in the U.S.S.R. the most outstanding geological discovery of the recent decades? No, the time of great geographical and geological discoveries is not over yet.

"But even this is not the point. Let us assume there are no more 'blank spots' on the earth. And yet the terrestrial landscape is not the most typical of our planet. All of the land does not constitute even 30 per cent of the earth's surface, whereas more than 70 per cent of it is covered with the eternally surging, periodically rising and falling tides of the world ocean. The ocean still conceals such mountain ranges as the Lomonosov Ridge. With the knowledge of only one-third of the hard surface of our planet we are unable to deduce any general laws of its structure. In the 21st century the scientists will undoubtedly have to draw up detailed geographical and geological maps of the ocean floor.

"Incidentally, it is not only a question of theoretical interest. Soviet oil derricks have already advanced far into the Caspian. There can be no doubt

that in the very nearest future minerals will be mined in the sea floor, of course, at first in shallow seas. Oil derricks will probably soon be seen in the Persian Gulf and the Red Sea. Then will come the turn of deeper places. Methods of mining minerals in the ocean floor, at a depth of 2 to 3 kilometres will be found. Man, the master of nature, will inevitably take possession of all the resources of our planet wherever they may be.

"Geologists are facing even greater prospects. Can they possibly be satisfied with the knowledge of only the thin layer on the very surface of the earth? The greatest depth reached by a boring bit to date is 5,000-6,000 metres. Even if we presume to know the entire surface of the earth to this depth geologically, comparatively it is less than knowing the thickness of an apple peal. In the meantime reflected sound waves are perhaps the only thing that bring us information of the maximum depths of the earth. As a matter of fact, we do not know as yet whether the core of our planet is heated to stellar temperatures, has a relatively low temperature of 1,500 to 2,000 degrees or has retained the primordial cold of the outer space. I think that by the 21st century man will have studied the first 20 or 30 kilometres of the earth's crust. Of course, man will also have considerably extended his knowledge of the core of our planet.

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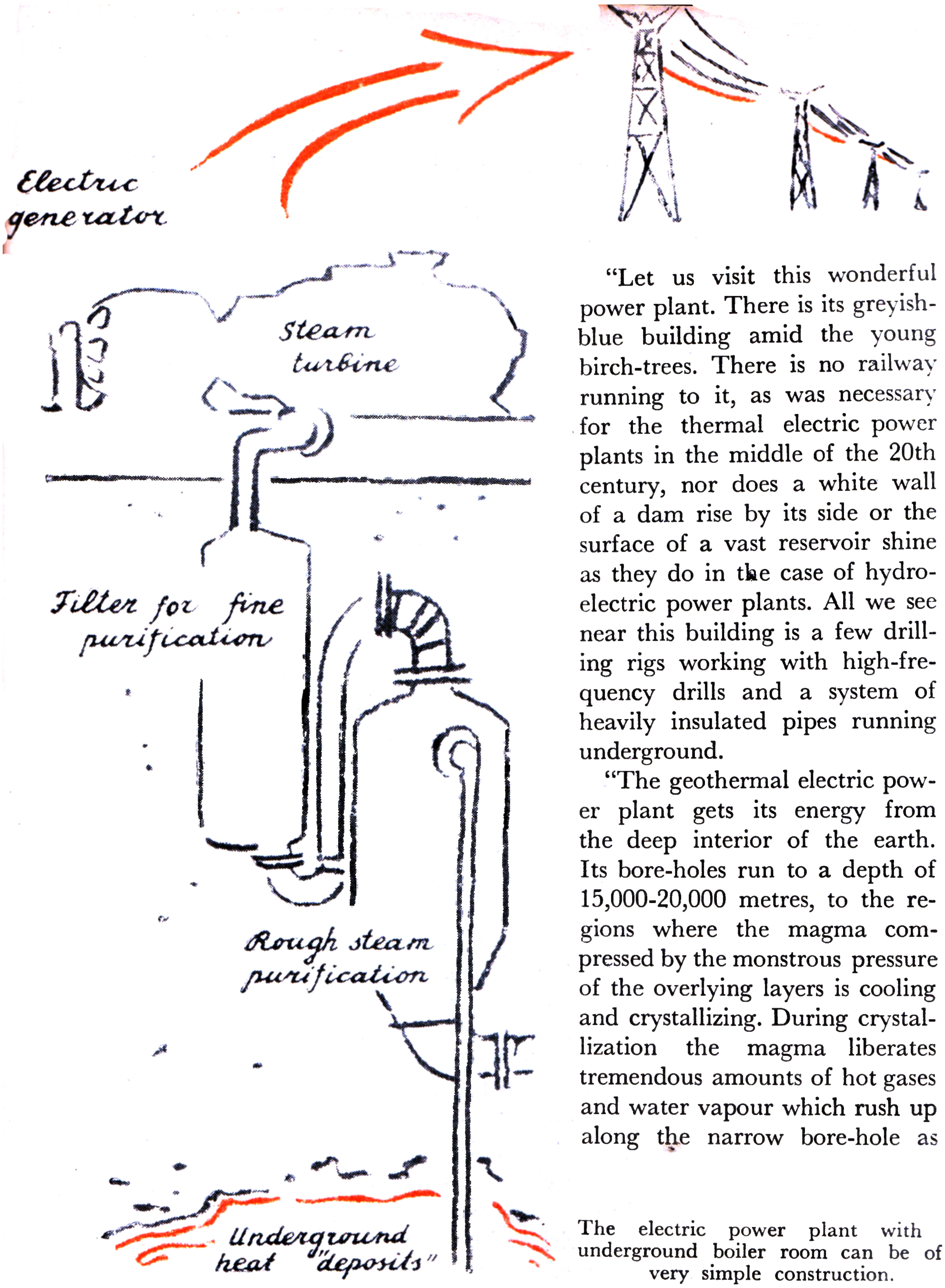
Underground Heat

"And so geologists will descend deeper into the interior of the earth and will study it by direct and indirect methods. In connection with this I should like to dwell on a certain peculiar 'mineral' which is hardly used today but which will undoubtedly find very wide application in the future. This 'mineral' is underground heat.

"The electric power plants in Larderello, Italy, and the heating plants in the capital of Iceland and of individual enterprises in Japan, the U.S.A. and our Kamchatka are perhaps the only consumers of this underground heat today. But this is a powerful source of literally ubiquitous energy. Volcanoes, geysers and hot springs are only cracks and fissures along which this energy seeps through to the surface.

"Of course, in the beginning it will be expedient to build geothermal electric power plants wherever this heat is close to the earth's surface, where there are natural outflows of hot steam or water, say, in Kamchatka, land of active volcanoes and geysers, and in some areas of the Caucasus and Central Asia. But it is only a matter of getting down to the necessary depth, because there is heat everywhere. Some day a geothermal electric power plant will probably be built near Moscow, too.



"Let us visit this wonderful power plant. There is its greyish-blue building amid the young birch-trees. There is no railway running to it, as was necessary for the thermal electric power plants in the middle of the 20th century, nor does a white wall of a dam rise by its side or the surface of a vast reservoir shine as they do in the case of hydro-electric power plants. All we see near this building is a few drilling rigs working with high-frequency drills and a system of heavily insulated pipes running underground.

"The geothermal electric power plant gets its energy from the deep interior of the earth. Its bore-holes run to a depth of 15,000-20,000 metres, to the regions where the magma compressed by the monstrous pressure of the overlying layers is cooling and crystallizing. During crystallization the magma liberates tremendous amounts of hot gases and water vapour which rush up along the narrow bore-hole as

The electric power plant with an underground boiler room can be of a very simple construction.

though through the crater of a volcano. But this volcano has been tamed by man, the masses of gas and steam being caught up by pipes run to separators where the vapours of rare elements are isolated and condensed, and the noxious admixtures, steam, etc., are separated. Thus this electric power plant is at once a plant producing helium and hydrogen, magnesium and aluminium, calcium and sulphur, as well as many other substances for the needs of the national economy.

The Ore of the Future

"Let us go into the shops. Some of them work on semi-conductors. Chemical elements and their mixtures compressed in large condensers and hardening in moulds heat semi-conductor batteries in which electrical current is generated."

An even rumble of machines reached our ears from the adjacent room. It was gas and steam turbines driving generators, typical of the early 21st century power industry in which the mechanical electrical generators at thermal power plants had not yet been fully supplanted by semi-conductor thermoelements.

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The academician stopped for a moment and put his hand on the fragment of rock that had attracted our attention from the very beginning of our conversation.

"Here is one more mineral with a great future. It is basalt which is practically ubiquitous.

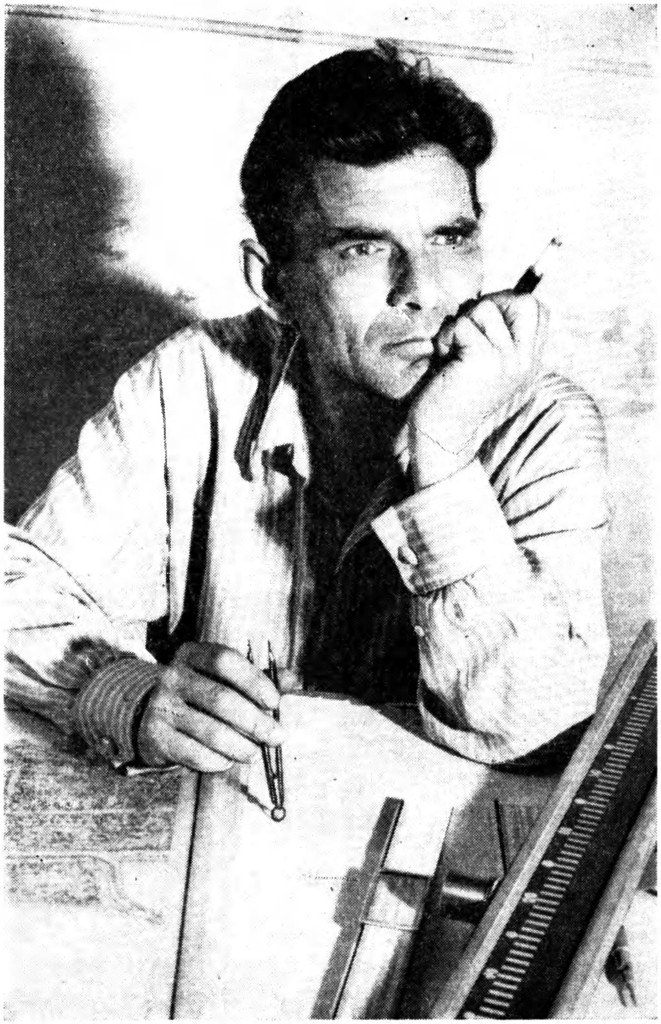
"Basalt, dark-green or black, brown or grey, dense or porous, is the principal igneous rock. It forms whole mountain ranges. Fiery basalt streams are poured out by the volcanoes of present-day Hawaii, Iceland, Kamchatka, etc. A thick layer of basalt can probably be found everywhere under layers of sedimentary rocks and underlying granite. Basalt usually contains 20-25 per cent iron, about as much magnesium, somewhat less calcium, 3-5 per cent potassium and sodium oxides, some aluminium and silicic acid. Usually it also contains other elements, including rare and precious metals. It does not pay to produce iron from basalt because we now have ores containing much more of this metal. Nor does it pay to produce separately magnesium or calcium from basalt. But if combined production of iron, calcium, magnesium, aluminium and other elements could be organized such processing of basalt would scarcely leave any wastes.

"In a number of countries the richest iron ores, as well as other elements, have been either completely worked out or are on the verge of exhaustion.

It can be safely said, though, that basalt, the ore of the future, can be found in unlimited quantities in almost any country. Metallurgical engineering of the future will also be able to process a number of other ores which are either not used today at all or are used only for one of their constituents.

"I want to say a few more words about geography exhausing itself as a science. I think the very nature of this science will change in the nearest future. From passively descriptive it will become vigorously active. These two periods can be discerned in the history of nearly every science: the first period during which facts are accumulated and certain laws of nature are discovered, and the second period during which these laws begin to be actively used.

"The geographer of the future will devote his endeavours to actively changing the nature of various areas, regions or perhaps even whole continents. The studies of the effect of warm ocean currents already make it possible to predict the changes in the climate if their direction is somewhat altered. The geographers of the future will probably study the results of the changes in the direction not only of the sea currents but also of the air currents, and the society of the future will be able to effect these changes. Then a stable humid climate will be created in the deserts, and the latter will blossom out. The permafrost in Siberia, North America and perhaps in Greenland will thaw. The markedly continental climate of the central regions of continents will grow milder, etc. In general the geographer will change from a describer to a remaker of nature."



Pulse of the Tatar Strait

In a woman's soft voice the loudspeaker announced: "Passengers who have arrived by the Moscow-Sakhalin plane may reach any point on the island by helicopter, train or launch."

It was a bright July morning. The summer of 2010 was generally quiet and windless. We decided to go by launch and bought tickets to the famous Sakhalin dam. When the small craft pushed off we began to recall all we knew about this ingenious and unique structure.

The idea of connecting Sakhalin with the mainland had occurred long ago.

It had been voiced as early as the middle of the 19th century by Gennady Nevelskoi who in 1849-1855 had discovered a strait, later given his name, and proved Sakhalin to be an island and not a peninsula as had then been believed. Some people proposed to organize across the Tatar Strait a ferry service capable of ferrying whole trainloads. But what about winter when the Strait freezes?

Others had proposed to drive a tunnel under the Strait but this would have been too expensive.

In 1951 engineer Nikolai Romanov visited the island, as a member of a large expedition, and was surprised at the climatic contrasts on and around it. Sakhalin stretches along the mainland. In the north it was washed by the cold Sea of Okhotsk and in the south by the warm Sea of Japan. In the northern part of the island it was cold. Tundra or marshy taiga scrub stretched all along the coast from the Bay of Baikal to Cape Tiek. In the southern part of the island it was much warmer and nature was richer. The people who came here to develop the island, extract the Sakhalin oil and mine coal and other valuable minerals had it easier. The Kuroshio warm current approaching Sakhalin from the south turned off before it reached the Tatar Strait, frightened, as it were, of its narrowness, and took its life-giving warmth to the Pacific.

Could this current be turned so that it ran through the Tatar Strait, made warmer not only Northern Sakhalin but also the shores of the Sea of Okhotsk and changed the climate of the Far-Eastern coast? This problem appeared even more important than organizing a ferry service or driving a tunnel between Sakhalin and the mainland.

To create a current from the Sea of Japan to the Sea of Okhotsk through the Tatar Strait, P. Koloskov, a Soviet scientist, proposed, as far back as 1931, to divide the Amur waters into two streams, directing one of them to the southern part of the Tatar Strait. In this case the warm Amur waters would flow to the bay in the vicinity of De-Castri. The sea currents would tend to flow north, to the Sea of Okhotsk. It was a very interesting project but there was no certainty that such currents would arise.

Engineer N. Romanov stood on the shore of the Strait for hours on end and looked at the turmoil of the waves seething before him. Here the tides collided, and immense masses of water rushing northward protested, as it were, against being forcibly driven back. One day an extraordinarily interesting idea had occurred to Romanov. Later this idea was embodied in an

engineering project which was carried into life about 30 years ago in the 1970s. The essence of this project is. . . .

At this moment we entered the narrowest part of the Tatar Strait—the Nevelskoi Strait. At this point the distance between the island and the mainland is only 7 kilometres. Ahead of us a rather low dam came into view. This dam joined the shores of Cape Lazarev on the mainland and Cape Pogibi on the island. A train and cars crossing the dam could now be seen with the naked eye. Well then, the Strait was dammed. But why? And how can ships go through?

The petty officer of the launch, a veteran seaman, looked through the open door of the wheel-house at the screen of the ground radar and informed us:

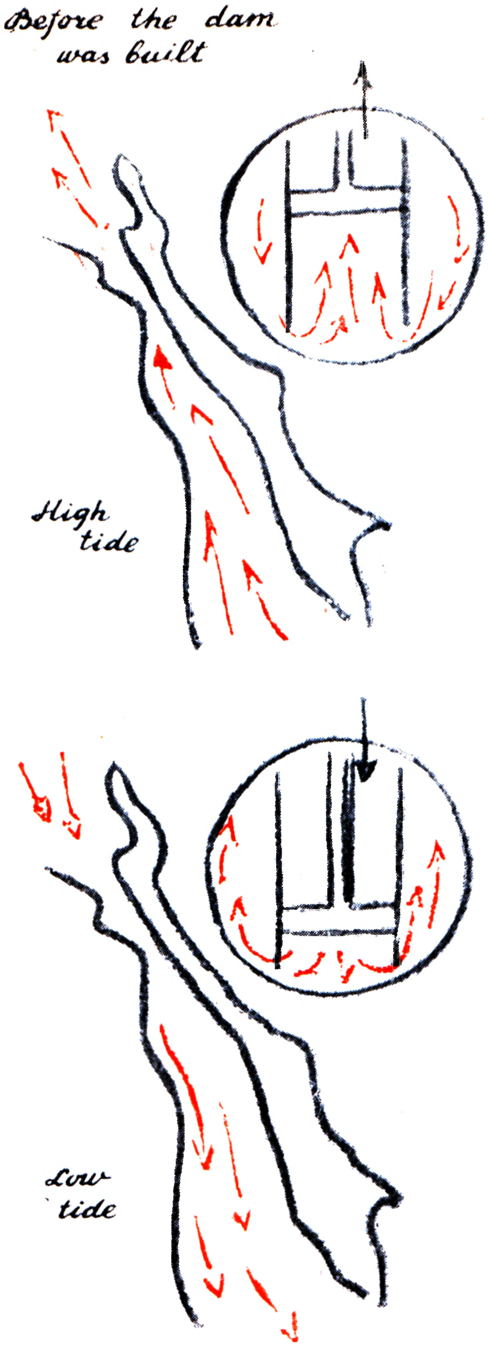
"It is not very deep here; three or four metres, rarely 10 to 15. It is deepest—25-27 metres—only in the fairway, in the middle of the Strait.

"Formerly the Strait was open only in summer, now it is navigable the year round. Take a field-glass."

The dam rose only about two metres above the surface of the water.

"Here the tides are low, and the water never goes over the dam," the petty officer explained.

The launch was steered directly towards the dam. It was time for the high tide to begin. Through the field-glass we could clearly see 100-metre steel gates



You cannot get very far with a pump that has no valve.

slowly opening a section of about 600 metres in the centre of the dam that is seven kilometres long. The gates were afloat on pontoons and simultaneously served as a drawbridge. The way through the dam was open to ships as well.

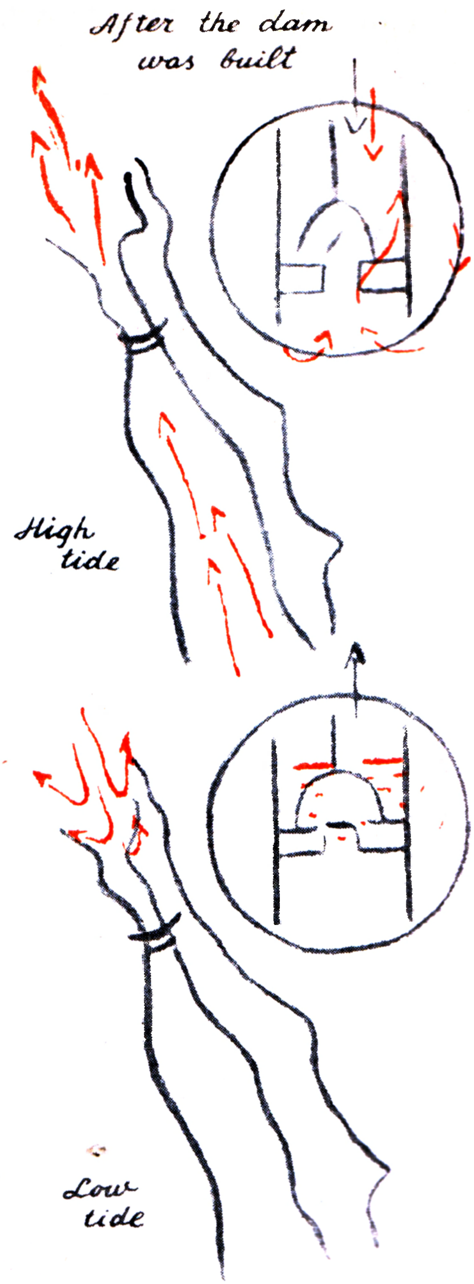
Smaller gates opened on the left and right of the main gates. The launch had now reached the dam.

The petty officer ordered the engine to be stopped and said to us: "We shall drift with the curent wherever it takes us."

The rising tide caught up the little craft and carried it through the gates rapidly. The helmsman barely manipulated the wheel keeping the bow of the launch on its course. Neither of us correspondents was a seaman but we saw that the current travelled at the rate of three or four metres a second.

"There are two high tides a day," said the petty officer. "Every six hours high tide is followed by low tide, and the water in the Strait begins to move in the opposite direction.

"Three cubic kilometres of water daily passes north through the gates. This is four times as much as is discharged by the Volga, the Don, and the Dnieper all told. It is more than is discharged by the water-abounding Amur. Before the dam was built these cubic kilometres of warm water returned with the low tide. The water was driven back and forth in the



Just put a valve in and see what you can do then.

Strait. But now, as soon as low tide begins, the gates close by themselves, the warm water remains on the other side of the dam and is carried by the low tide into the Sea of Okhotsk. The Sakhalin dam is a valve that passes the warm water only in one direction—northward. It is like a big pump that pumps the Sea of Japan into the Sea of Okhotsk. It works on "lunar" power, since it is the moon's attraction that creates the tides and makes the water move."

The pulsating current draws one of the branches of the Kuroshio into the Tatar Strait.

"The pump has been working for 30 years," said the petty officer. "I remember 1970 when they began to fill the dam. It took 3 million cubic metres of stone and earth and 1 million cubic metres of concrete. The 29-metre-wide dam cost one-third as much as a tunnel under the Strait. And think of the wonders it has worked for Sakhalin, the natural changes you could not buy for any money.

"Before 1970 we walked across the Nevelskoi Strait. The ice was a metre thick, heavy enough for an ice-breaker, although about 5 kilometres south there was no ice at all, and ships had to sail from Vladivostok to the Sea of Okhotsk in a roundabout way, through the La Pérouse Strait past Japan. Today we have our own internal route.

"I remember there was a red line—the January isotherm—on the maps. Ten-degree frosts prevailed here. It was a 'front-line' which the Arctic held very firmly. It was even referred to as the 'minus 10 isotherm.' It reached Cape Lazarev, skirted Sakhalin and ran along the Okhotsk coast on the other side. Now it is not on Sakhalin any more. The warm current has moved it somewhere to Anadyr, to Chukotka.

"The mean annual temperature of the Okhotsk coast has risen about 10 degrees during these 30 years. Ice is a rare occurrence in the Sea of Okhotsk. The geographers are all agog." The petty officer laughed. "They have lost their pole of cold. It left Oimyakon, and now not a single expedition has been able to find the coldest place in Eastern Siberia in several years. The pole keeps moving northward. During the few dozen years that have elapsed the 'pump' would have pumped the Sea of Japan dry if it had not been for the warm waters of the ocean that keep refilling it.

"As for us, seamen, the current helps us, too. The famous Amur waves carry silt and sand into the Nevelskoi Strait where there is not very much room as it is. The Strait would long since have grown shallow if it had not been for the sea current that cleans out the fairway."

We were approaching the large, new port of Sakhalin. Oil tankers flying the flags of Indonesia, Viet-Nam, Japan and other countries were crowded at its piers.

"And what about the Japanese, Officer? Have they lost anything with this turn of the Kuroshio?" we asked.

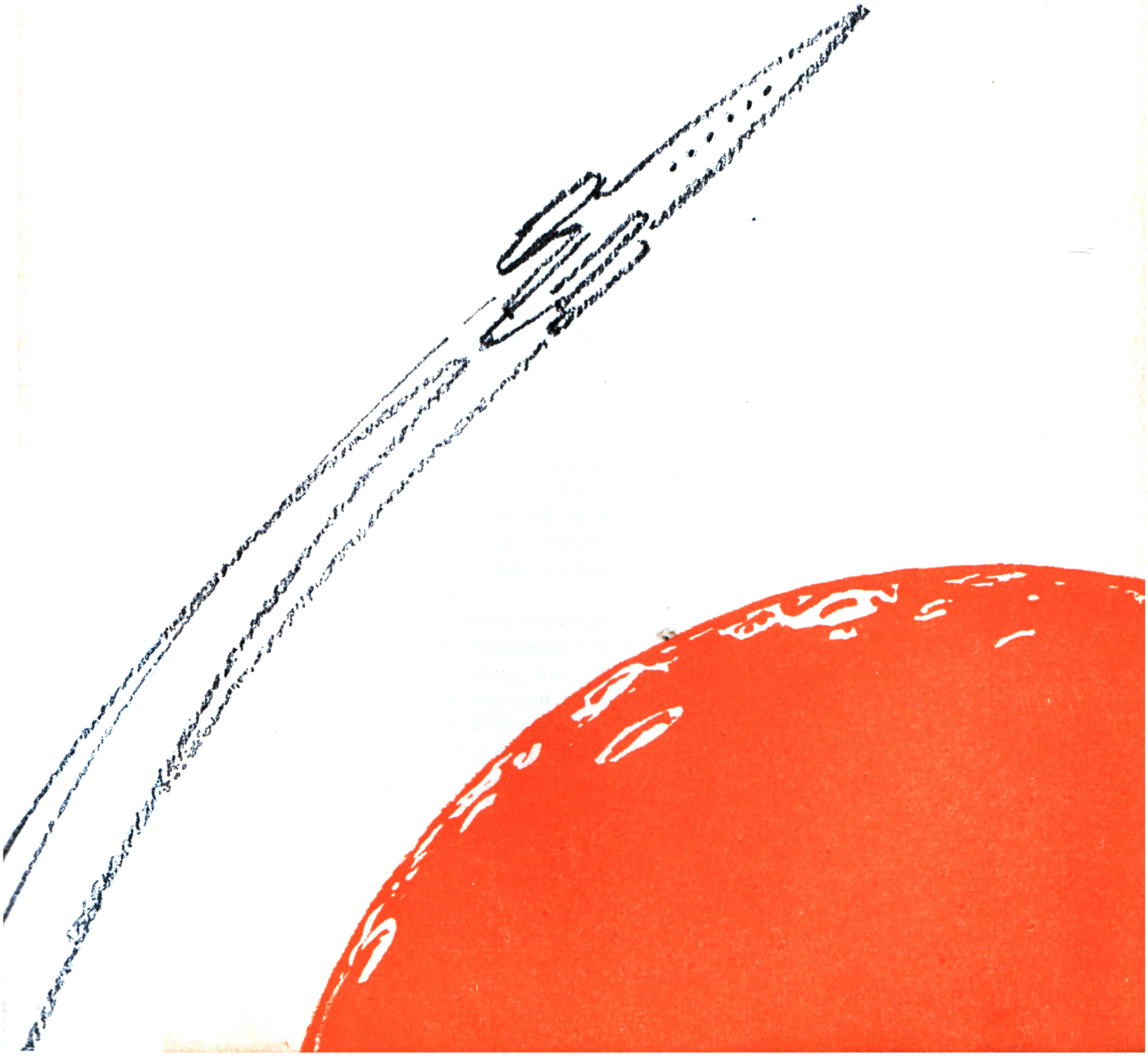
"Why, no! On the contrary. Recently Japanese fishermen who live on the northern Japanese islands came here to celebrate the 30th anniversary of the Sakhalin dam. Only those who liked skiing felt a bit put out. There has been no snow on those islands for the last 10 or 15 years. The climate has improved and has become more stable."

The petty officer went to the side of the launch and, in keeping with the old sailors' tradition, shouted to the non-existing sailors:

"Cast off!"

The above picture rose before our mind's eye as we listened to the story of the very stern-looking, very reticent, but actually very cordial and affable person—engineer Nikolai Romanov, author of the project of the Sakhalin dam which will be able radically to change the climate of the entire Soviet Far-Eastern coast.

DISTANT VOYAGES



Lunar City

Through Interstellar Abysses

Interplanetary flying is the most fascinating, most thrilling and most sublime (as regards its possible effects on the whole of human culture) scientific and technical problem now facing science and engineering. And it will not be long before this problem is solved.

Incidentally, it all depends on what you consider a solution of this problem. The first automatic satellites of the earth started off on their space journey in 1957. Soon afterwards a Soviet rocket hit the moon and then another Soviet space laboratory photographed the invisible side of the moon. By the end of the century man will probably visit the neighbouring planets. Which of these stages is to be considered the solution of this grandest problem? Yet ahead of us are studies of the more distant planets and of the interstellar space surrounding the solar system, voyages to the planetary systems of the closest stars, etc.

Whatever stage we may regard as the beginning of the era of interplanetary communication we shall never be able to reach its end. Every decade, every century, every millennium of the era, during which man may extend his will and thought beyond the limits of the earth, out into the universe, will bring ever new discoveries and ever new achievements. Man will never discover the whole of the universe, all of its stars and planets, as he has discovered all the continents and, we must take it, all in any way significant islands on the face of the earth. Among the captains of the future space ships there will be many Columbuses who will be able to say: "We have discovered new worlds." But there will not be a single Magellan who will dare say: "I have circumnavigated the universe." The universe is infinite, and infinite are the potentialities of the human mind in cognizing it.

The numerous sciences of interplanetary communication—they are sometimes generally referred to as astronautics—are developing very rapidly. Each day brings new ideas, ascertainment of the old calculations, and new data furnished by experiments and observations. Of course, we could not even try to describe in this brief chapter all the studies, forecasts and assumptions. This requires a book, and perhaps several books. Here we offer but a few new ideas, several snapshots from the astronautics of the future as it can be conceived today.

Lunar City

"Valery Bryusov, a very talented and very interesting poet lived and worked during the first quarter of our century. He had a good knowledge of the past—human history—and thought a great deal about man's future. He believed that the day would come when a 'single city would hide the earth under sparkling glass as under scales.' In one of his plays he depicted the decline of life on the decrepit earth covered with such a single glass city beyond which there was not even a trace of the dispersed atmosphere. But this time Bryusov was wrong.

Bryusov Was Wrong

"The future of mankind is not an ignominious death in the stuffy greenhouse air of the glass box. 'At first man will timidly penetrate beyond the atmosphere and then will conquer all the space around the sun,' prophesied K. Tsiolkovsky. Glass cities with an artificial atmosphere, large greenhouses, solar power plants and

everything that is necessary to create the complete circulation of substances required for the living organism will come into being not on the earth but on the other bodies of the solar system."

Our interlocutor, Nikolai Varvarov, Chairman of the Section of Astronautics of the Voluntary Society for Aiding the Army, Navy and Air Force, paused briefly.

"The first of these cities will spring up on the moon. Look at the photographs of our satellite. All these lunar cirques and craters look as if they have been made by nature herself for the purpose of building large glass-roofed greenhouse cities.

"The attack on space began with the launching of the Soviet artificial earth satellites. The next stage will be an attack on the moon by means of automatic mobile laboratories followed by expeditions of scientists representing various branches of science. And then man will face the problem of developing a permanent settled area on the moon, a base and refuelling station for the space ships starting off on long voyages to the neighbouring planets.

Gold Loaves and Diamond Shoes

"Of course, in the beginning we shall have to supply our moon settlers with all they need from the earth. But this will be very expensive. A loaf of bread brought to the moon from the earth will cost as much as a brick of gold of the same size costs on the earth. For this reason one of the first problems will be to make the moon self-sufficient. I think that by the beginning of the 21st century this problem will be solved if....

"This 'if' is the possibility of peaceful development of mankind. We, Soviet astronauts, like the astronauts of the rest of the world, are vitally interested in safeguarding and ensuring a lasting peace among all the peoples inhabiting our earth. Interplanetary flying can be achieved soon if the earth is not plunged into the infernal flames of an atomic war.

"I believe the peaceful forces will prevail and therefore I have the honour of inviting you for a jaunt through the first lunar city located in the crater of Eratosthenes."

... We were on the moon.

A specially designed automobile brought us from the spacedrome to our city along a smooth road laid out on the ledges of granite cliffs. It was a fine road neither eroded by rain or covered with dust. Here there was neither rain, wind, nor atmosphere. The fine automobile was entirely airtight and air-conditioned or else we should have been parched in its metal body heated by the direct rays of the sun.

The automobile entered a narrow tunnel driven in a cliff, and an aluminium gate opened before it. It was an air lock. In the city which we were about to enter the atmospheric pressure reached almost 500 mm. Hg, which is one-third below the sea-level pressure on the earth. But such air which, in addition, contains somewhat more oxygen than does the air on the earth is quite healthful. To prevent this air from escaping from under the glass roof of the city, all the exits were shut. The city could be entered or left only through the air locks.

Another aluminium door opened before our car, and we entered the city. Now we could get out of the car and breathe the humid and tense atmosphere created in the glass city on the moon.

Here Even Those Who Sleep in the Street Have a Roof Over Their Heads

To be sure, there was a many-layered, transparent vault over our heads. Some layers were of glass, others of plastics of different composition and properties. Here this thin glass roof took the place of the heavy mantle of the terrestrial atmosphere. The gases contained between the transparent ceilings also differed in composition. The roof served several very important purposes, namely, to admit to the city only that part of solar radiation which also reached the earth, to retain and aid in transforming into electric power that part of solar radiation which was also retained by the terrestrial atmosphere, to protect against meteorites, etc.

Rare aluminium columns supported aluminium casements with glass or plastic panes. It was not to prevent them from dropping to the surface of the moon that these columns supported the casements. On the contrary, they worked for pull; they pulled this ceiling towards the moon, otherwise it could be torn off by the air pressure.

We walked past flowering bushes and fruit-bearing trees. Not all of them could be easily recognized, although they were all children of the earth. Here, under the conditions of weak lunar attraction, ordinary radish grew up to the size of a date-palm and onions with spears 10 metres long.

Ahead of us was a glass wall with a double door. There were very many such walls here. They were set 800-1,000 metres apart and served about the same purpose as did the watertight bulkheads on ocean liners. If an ocean liner strikes a reef and springs a leak, the water fills only one compartment and the ship remains afloat. If a large meteorite went through the roof of the lunar city, it would kill the plants of only one section.

Aluminium, glass, plastics, water, soil—could all this have been brought from the earth?

No, the aluminium was produced by a local plant from local lunar ores. The glass and plastics were manufactured at lunar factories. Lunar water obtained from the interior of our satellite moistened the cultivated layers of the lunar soil. The oxygen and nitrogen of the city air were also obtained from lunar minerals. The daylight lamps which would be turned on here and would shine during the almost month-long night, the radiators to give the city heat in the meantime, the machines and furnaces working at the local plants and factories—all used the power produced by the local solar and atomic electric power plants.

Self-Sufficiency

The lunar city not only satisfied its own needs but also worked, so to speak, for export. It produced synthetic fuel for the rockets departing for the earth. Construction of a large space ship plant was being planned. Rockets manufactured in the shops of the lunar plant would soon start off on their long interplanetary travel.

An unusually motionless and furious sun was ablaze above the transparen city roof. Suddenly a pillar of fire, as straight as an arrow, shot into the zen rose beside the sun against the background of the black sky. It was rocket leaving the lunar spacedrome for Mercury with the first exp scientists from the earth.

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Visitor from an Antiworld

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Through Interstellar Abysses

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very atmosphere of the earth, the 21st century may never come. Today, for the first time in his history, man has a means capable of exterminating all life on our planet. I am taking advantage of this opportunity to add my voice to those who demand an immediate ban on the tests of all types of atom bombs and their use as a means of waging war.

"But I believe mankind will not commit suicide and the 21st century will come. And what a splendid century it will be!

"You know that very recently scientists have learned about the existence of so-called antiparticles, in a manner of speaking 'inside-out matter,' and have been able to produce some of them artificially. Regrettably, these antiparticles do not 'live' long under our conditions, disappearing almost as soon as they are 'born' (they exist a negligible fraction of a second). They disappear upon colliding with analogous particles. A tremendous quantity of energy is liberated during these collisions, hundreds of times as much as is liberated even by the hydrogen-helium nuclear reaction.

"Atoms and even molecules built entirely of antiparticles can be conceived. It is possible that in some remote regions of the universe there are whole galaxies built of antisubstance. Maybe the scientists on the planets of these galaxies have now obtained for the first time, with the aid of their proton-cyclotrons, elementary particles usual for our world and are examining and studying them with the same wonderment as we are examining and studying the antiparticles.

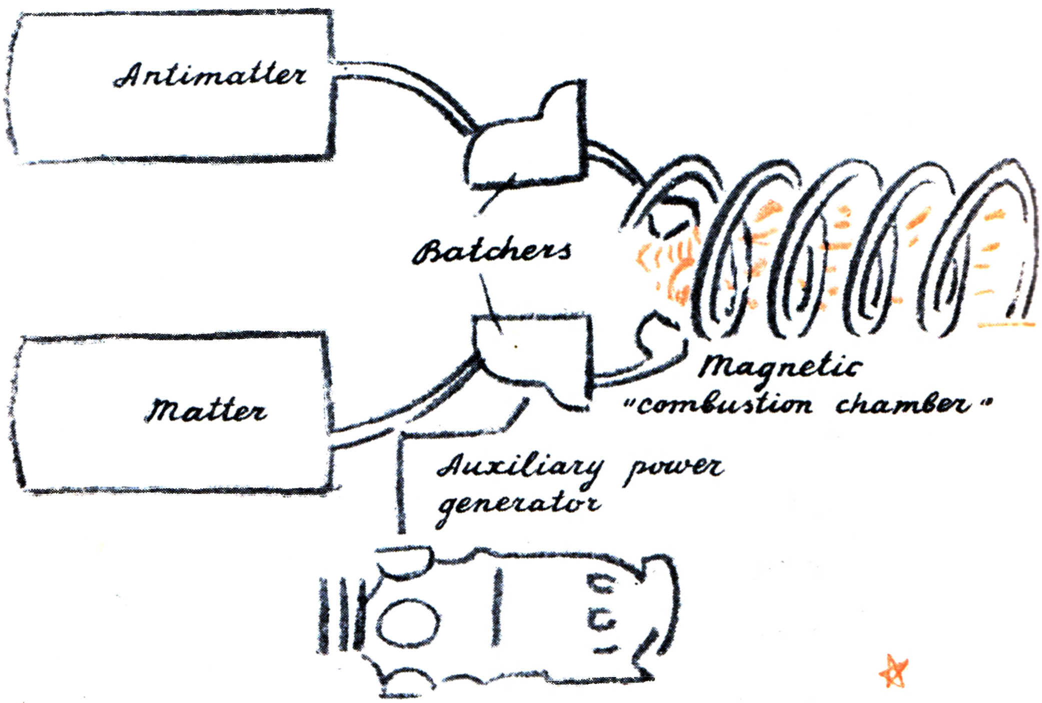
Visitor from an Antiworld

"Let us imagine the following facetious case. Some day a human being from this antiworld may come flying to our earth. Here he can exist only in some power glass case, something that clearly separates him from our substance. Then he falls in love with a girl made of our substance. This turns into a universal tragedy because their first kiss, their first contact causes a tremendous explosion.

"An explosion caused by the contact of substance and antisubstance. My principal line of research today is in the field of gas dynamics, and I am extraordinarily interested in the motion of the particles of substance occasioned by such an explosion. To gain an insight into the monstrous interlacing of gas and light waves by the hard knots of magnetic and gravitational fields, and in the chaos of disturbed subatomic forces, is an infinitely interesting and uncommonly complicated job. But today we can already imagine the relatively quiet operation of such a process of transformation of particles of matter and antimatter into quanta of electromagnetic fields, into rays of light.

"Such a 'quiet' operation of the process is possible if we feed matter and antimatter into a combustion chamber in the form of extremely rarefied gases either in small portions or in very thin jets.

"It is conceivable that scientists will be able, by surrounding the reacting substances with invisible but impenetrable walls of electromagnetic fields, to direct the products of this reaction—the stream of photons—one way. Then it will be possible to develop the most powerful theoretically conceivable engine—a photon rocket. I think that by the 21st century all the theoretical



work required for the practical construction of such an engine will be completed.

"And this engine will make possible interstellar flights that today seem utterly fantastic and incredible.

"About 50 years ago science reached an entirely new stage of development,

namely, theory went ahead of practice showing the latter the way. The steam engine was actually built in the metal first and the theory of its calculation was created afterwards. The jet propulsion engine, the latest engine of the modern high-speed plane, first came into being in the harmonious figures of mathematical formulas and was embodied in the metal afterwards. In our time any, in any way serious, discovery or invention is practically impossible without thorough theoretical preparation.

"In the middle of the 20th century scientists had in the main calculated the construction of interplanetary rockets, the trajectories of their flights, and the possibilities of communicating with and supplying the astronaust. But no interplanetary flight has been made yet. And all of us—I shall probably not go wrong if I say that not only scientists but all of humanity—are dreaming of the time when man will make his first flight to one of our neighbouring

Photon jet

The professor drew with a pencil the general outlines of the most powerful theoretically conceivable engine.

worlds. The scientists of the 21st century will, after completing their theoretical calculations, similarly dream of flying to the stars.

"We must say offhand that this problem will be vaster and much more complicated than the problem of interplanetary flights. We cannot even imagine as yet what giants the people of the 21st century will be to be able to dream of such things and to effect them.

"To show you how immense this problem is, I shall give a few figures. For example, it takes light from Proxima Centauri, the modest little star closest to our solar system and seen in the southern hemisphere, 4.27 years to reach our planet, a ray of light travelling at the rate of 300,000 kilometres a second.

"If we were to draw a scale picture showing the positions of the solar system and Proxima Centauri in relation to each other, we should have to

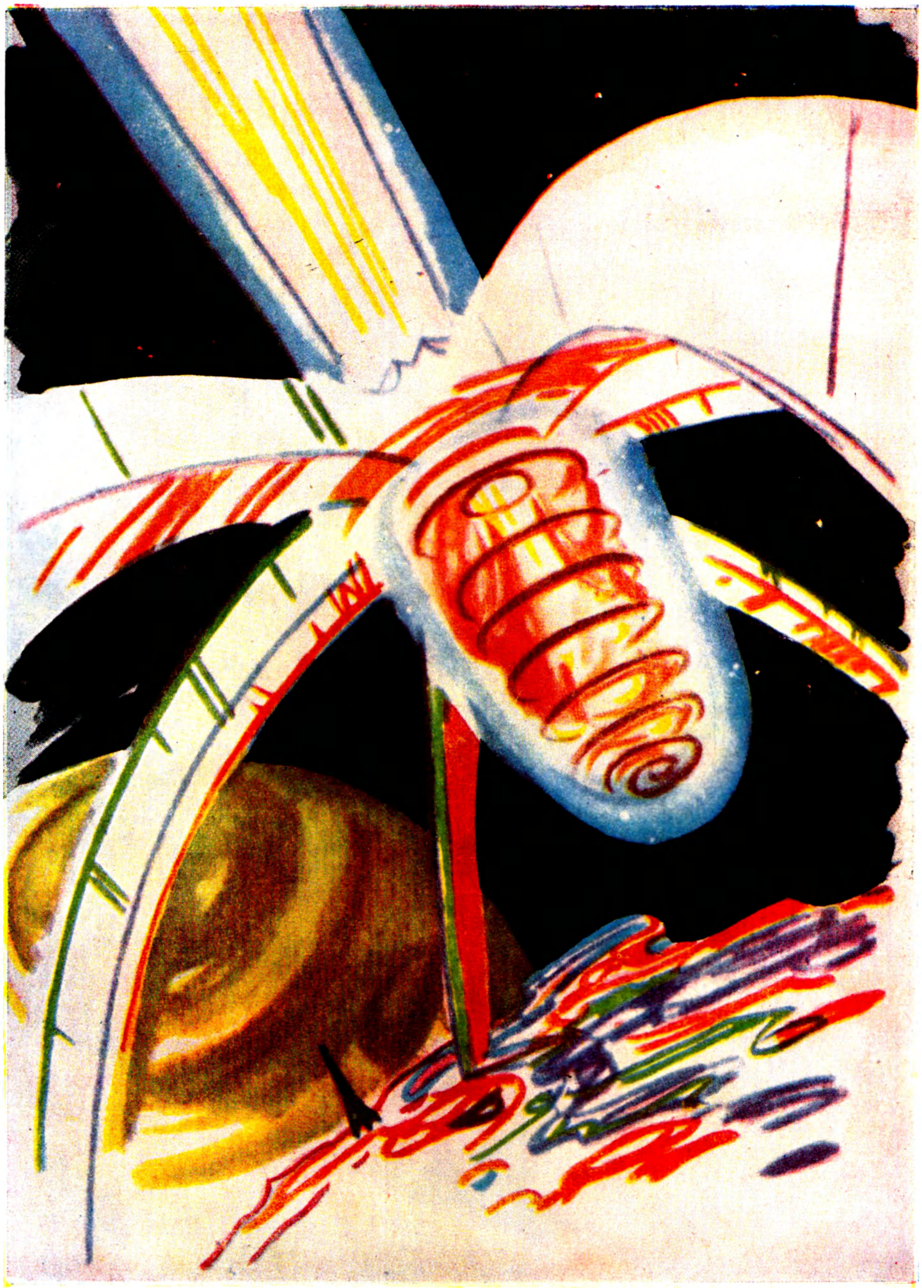
use a sheet of paper 30 kilometres long. In one of its corners we should mark the solar system in the form of a circle with a diameter a little under 5 mm. We should not be able to show the sun because on this scale it would have a diameter of a fraction of a micron. At the other end of the sheet, at a distance of 30 kilometres from our circle, we should have to mark a dot, also barely visible, and designate it with the beautiful name 'Proxima.' That is what an interstellar flight really means.

"It is quite probable that one of the satellites of Saturn or Jupiter, or perhaps a large asteroid, will be proposed as the basis for the interstellar ship. A requisite amount of antisubstance will be delivered to it, a gigantic engine will be installed on it, and one fine moment this heavenly body will leave its eternal route in the solar system and will rush into the black abyss of the universe. Of course, neither the 'combustion chamber' nor the 'jet' of this engine will resemble anything we know in the present-day engines. In all probability these will be annular magnetic fields regulating streams of matter and photons. The reaction jet, or the reaction ray, to be exact, thrust back by the interstellar ship, will be so intense that it will burn everything living long before it reaches the earth. It is precisely for this reason that the spacedrome for interstellar flying will be located so far from the earth.

"The flight of the photon rocket will be watched from the earth through very complex instruments. Today it is not as yet clear how it will be possible to maintain contact with it, since its speed will be very close to the marginal speed possible in nature, i.e., close to the speed of light in a void, to the speed of radio waves. Our ship will fly 250,000-280,000 kilometres a second if it 'burns' in its engines 90 per cent of its mass, i.e., the first stage of the rocket. Probably then all contact between the earth and its interstellar scout will be lost as soon as the engine is turned off.

"Ten to fifteen years will pass. And again a star will appear in the dark abysses of the universe. Its power ray shining in the direction of the solar system, like the beam of light thrown forward by a projector, this star will be moving in our direction with a fantastic speed. This power ray will be the photon engine turned on by the first astronauts for braking. A few daring manoeuvres and the ship will enter on one of the possible orbits and will again become a member of our solar system.

"I do not think this flight will be achieved in the 21st century. But I am firmly convinced that the 21st century scientists will calculate the interstellar trajectories, will draw up exact plans and will subject to mathematical analysis every detail of this project which is unthinkable today. And like us, who



Keen as a blade, the ray born in the fiery cloud of the magnetic "combustion chamber" was the propulsion jet of a gigantic interstellar ship.

have mastered all the continents and are dreaming of flying to the moon, they, who will have mastered all the planets of the solar system, will dream of this interstellar leap.

"What are the prospects for visiting the more distant stars?

"Today we can speak only of flights which might take—including the return—no more than 25 years, i.e., to planetary systems no farther away than 9-10 light years. It is scarcely advisable to send on a space flight a ship whose passengers might either never come back to earth or might spend their lifetime on the way. However, some inferences from Einstein's theory of relativity offer new and extraordinarily interesting prospects in this respect.

"The essence of these inferences is that as the speed of the interstellar ship approaches that of light the run of time on the ship will slow down compared with the terrestrial time.

"One hundred years may elapse according to the terrestrial timepieces, and during this time the interstellar ship will really have traversed a space (also measured from the earth) of nearly 100 light years. In the meantime only two or three years will have elapsed according to the timepiece on the interstellar ship, and the people on this ship will have aged precisely by this period of time. They will have visited planets and stars tremendous distances away from our sun and will have started back, the return trip likewise taking two or three years. But upon their return to the earth they will not find any of those people who had seen them off because 200 years will have passed on the earth during that time.

"Maybe such argonauts of the universe, people for whom the furious speed of motion will almost stop time, will be able to explore all the remotest corners of our galaxy and perhaps to visit the neighbouring galaxies. And the coming generations will pass them on—eternally alive—to each other like a relay baton.

"At one time the inferences from Einstein's theory of relativity seemed no more than curious and purely theoretical paradoxes. Today, when physicists calculate the accelerators of elementary particles, nuclear reactions and transformations, they can no longer fail to take into account the postulates of this theory.

"The time will come, and the pilots of the gigantic interstellar ships will also take these postulates into account.

"But these are also problems which the 21st century scientists and engineers will as yet only dream of solving."

We have come to the end of our reports from the 21st century. Getting out of our machine of time, i.e., our Pobeda at the entrance to the editorial offices for the last time, we must apologize once more and likewise once more express our gratitude.

We must apologize to the readers for the incompleteness and insufficient coherence between the different chapters forming our reports. Some readers may find the same ideas reiterated in our book and some may reproach the book for not being consistent enough in the views of the science and engineering of the future and may even point out contradictions.

We agree that the reports are incomplete and that there are reiteration and inconsistence and—it is terrible to say!—even contradictions. Nor can it be helped. In the book we have given voice to the opinions of many different people each of whom thinks his own way and conceives the future of science and engineering also in his own way. We do not deem it necessary to ascertain the exact quantity of electric power to be produced in our country in the year 2010, which differs in the statements made by different scientists. We believe it proper that each scientist should have his own idea of the 2010 model car, otherwise what will the automobile-building engineers be arguing about in their designing offices for the next 50 years? Let these contradictions be. It will be a very good thing if after weighing all the "pros" and "cons" the reader will subscribe to some opinion or other and will perhaps want to do something to help carry it into life. Frankly speaking, the main aim of our book is to start the reader thinking along these lines.

We wish to thank all scientists, engineers and technicians who helped us write this book by what they told us.

TO THE READER

The Foreign Languages Publishing House would be grateful for your comments on the content, translation and design of this book. We would also be pleased to receive any other suggestions you may wish to make.

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М. ВАСИЛЬЕВ и С. ГУЩЕВ

РЕПОРТАЖ ИЗ XXI ВЕКА

Рассказы двадцати семи советских ученых о науке и технике будущего